Complex Ecologies: Micro-Evidence for Storage Landscapes in Early Bronze Age Lebanon

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ABSTRACT

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This dissertation presents the results of an archaeological investigation into the environmental strategies of emergent aggregated societies in coastal Lebanon over the course of the Early Bronze Age (c. 3200-2400 BCE). The Early Bronze Age marked not only the rise of large-scale urbanized polities in neighboring regions of Mesopotamia and, to a lesser extent, the Southern Levant, but it took place during the dramatic climate variability of the Middle Holocene. This dissertation uses the analysis of microbotanical and ground stone tool data to assess agricultural strategies, land use, and plant processing technologies at two settlements along the Lebanese littoral during this time of political and climatic upheaval. By comparing phytolith data, stone tool use-wear and microbotanical residues from grinding tools from the sites of Sidon and Tell Fadous-Kfarabida, this project reconstructs local plant and stone environments and the choices that populations were making about those resources over time. It concludes that selectivity between conservative and innovative plant management technologies allowed these settlements to maintain small-scale local networks built into the

landscape and to participate with, while resisting incorporation into, growing urban and state economies nearby.

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Dedication

To Grey, Nemo, Castor, Pollux, and Moon, who drew me out of the darkest hours and remind me always of the joy to be found in the interconnectness of humans, non-humans and the places they make together.

Chapter One: Introduction

I have a word to tell you,
a message to recount to you:
the word of the tree and the whisper of the stone,
the murmur of the heavens to the earth,
of the seas to the stars.
I understand the lightning that the heavens
do not know,
the word that people do not know
and earth's masses cannot understand.
Come, and I will reveal it.

- Invitation from Baal to his sister Anat in The Ugaritic Baal Cycle, Tablet 4, Column 4 (Coogan and Smith, 121).

1.1 Research Themes

This is a dissertation about the interaction of people with their places – specifically, how people living in Early Bronze Age (c. 3900-2400 BCE; EBA) coastal Lebanon interacted with their local botanical and geological environments to create places that afforded them a range of options in the face of various and uncertain possible futures. To examine this process, this dissertation presents the results of a study of the micro-traceological evidence (including phytoliths and lithic use-wear) that I will suggest reflect choices EBA populations were making to create systems of storage in on-site constructions, and in their tools. Using these lines of evidence, I will suggest that these systems of storage, often only visible across thousands of years through the microscope, represent ways of storing knowledge and opportunity in relation to changing socio-economic organization across generations negotiating what Greenberg calls the very "different and mutable landscapes of the EBA Levant" (2003: 18). I will propose that we think about cycles of landscape and settlement use patterns as intentional behaviors that attempt to hold the land in balance according to Canaanite concepts of just leadership, and that the available texts suggest that this can only exist in balance with the gods and through the land. As has been well articulated elsewhere, "places not only *are*, they *happen* (and it is because they happen that they lend themselves so well to narration, whether as history or as story)" (Casey 1996: 27). This dissertation brings together plant, stone and human histories to explore how the coastal settlements at Tell Fadous-Kfarabida (TFK) and Sidon happened over the course of the third millennium BCE through the production of storage landscapes.

The development of storage capabilities and capacities has a fundamental place in the history of archaeological interpretations of the past. Since anthropologists began to theorize the mechanisms and catalysts of social change during the discipline's earliest years, storage has stood as an icon of transition and increasing social complexity. Lewis Morgan's stages of cultural evolution (1878), the cultural ecology of Steward (1955)[1], Fried's relationships of economic distribution to organizational type (1967), Service's well-known categorization of band, tribe, chiefdom and state (1962), further developed in the movements from "Big Man" to ranked societies proposed by Sahlins (1963), all incorporated, in their own ways, the idea of storage as an attribute that fundamentally altered human societies. Archaeologists, too, have worked with this idea since very early on, and continue to do so: from the great cultural

[1] Storage appears as one of the key secondary practices to emerge from Steward's shared "culture core"; indeed, one of his most famous students, Sidney Mintz carries on this Marxian historical materialism in his examination of food and power in modern U.S. history.

Revolutions envisioned by Gordon Childe (1936, 1942, 1950), to the Creation of Inequality as elaborated by Marcus and Flannery (2012), storage systems are prominent in their radical capacity for transformation, for good or for ill.

This dissertation builds on this literature, especially in that storage wasn't just important in its innovative aspects and its progressive changing power, but also in its conservative aspects, in the ways that storage helped ancient societies to negotiate between risky new endeavors and safer, better understood traditional modes of engagement with their environments. This is a classic model for resiliency as societies moderate between more tightly organized central leadership and more loosely organized networks of authority (Ibid). Storage is a way of thinking about mechanisms of resilience through the relationship of people to the land and to each other.

To address these ideas, I analyze the micro-traces of plants and stones found in different contexts from two Early Bronze Age (EBA) sites in coastal Lebanon: Tell Fadous-Kfarabida (TFK) in the north, and Sidon in the south (**FIGURE 1.1**). I use these micro-analyses to assess the ways in which the early complex communities in question modified and curated their botanical and geological resources to create systems of storage over the course of their aggregation trajectories during the EBA. I will first look at the history of research in this area for the coastal Levant to establish the existing climactic, archaeobotanical, and settlement history records as they are understood. I will then present the vegetation and geological zones in use over time on each site as represented by the phytolith data, and in relation to known climactic variation and settlement development over the course of the EBA. I proceed by analyzing the phytoliths from on-site storage compartments at each site, to illustrate how features more traditionally identified for storage, and particularly for the storage of more traditionally studied staple crops, relied on the preservation of less-visible parts of the landscape – in particular, wetland resources. In some ways, the technologies of the storage systems themselves at these sites reveal more than the contents of the bins themselves, as they demonstrate a reliance on wild plant resources. I then introduce a pilot study of ground stone tool micro-wear traces, to illustrate the ways in which processing techniques and materials are also implicated in the integrated practices of storing possibility and knowledge over the long and short term. Finally, I conclude with a discussion of the ways in which these different presentations of storage data come together to offer possibilities for interpreting interconnected storage landscapes and practices in two EBA aggregated societies in coastal Lebanon, and how those practices further integrate with Bronze Age notions of just and justified socio-political authority.

1.2 What is Storage in the Archaeological Record?

Storage is a familiar and frequently invoked feature of complex societies, both in the present and in the archaeological record. However, it manifests in many different ways, and is employed towards many different ends. In general, when archaeologists talk about "storage," they are referring to constructed places – bins, compartments, houses, pits – for keeping things for a later time, or sometimes to the containers within which those things can be kept or transported (Paulette 2015; Bevan 2013). Most frequently in the literature of the Mediterranean and Southwest Asia, the things being kept are plant foodstuffs like grains, oil, and legumes, although in some environments the storage of meat or seafoods is also practiced. There are also storage facilities for prestige items, toolkits, administrative and/or religious records, and any other number of things that might have value and use for a society at a future time (Rothman and Manzanilla 2012). This is the key to storage: it implies an imagined future over which the society in question can produce some degree of control, as they are able to provide for those imagined future needs and desires via present practices and technologies of preservation. Ethnographically, we see that these kinds of material storage can be viewed as a good thing, encouraged and exploited for risk management, but can also be viewed as a negative in that they bring with them the potential for hoarding and destabilization of social balances (Lee 1969; Marcus and Flannery 2012). It is important to remember, therefore, that the development of storage technologies should not necessarily be considered as part of a linear progression, any more than any other unique feature on a site, but must be studied carefully within its social context.

Such detailed studies of storage can prove challenging, however – previous archaeological researchers have noted the difficulty of identifying the extent and nature of early storage practices beyond those identifiable structures for storing materials, as they can occur in ways that are neither visible nor material (Testart 1982; Ingold 1983; Forbes and Foxhall 1995; Stopp 2002; Kuijt 2009; Paulette 2015). In some cases, the "storage of social obligations" in the form of reciprocal behaviors that act as insurance in times of future need are clearly more important than the storage of material goods (Weissner 1977). With this dissertation, I analyze the traces of several kinds of storage in Early Bronze Age coastal Lebanon, including the constructed compartments for storing plant resources, and the behaviors in relation to the landscape that preserved within in it possibilities for a range of different kinds of action in the imagined future of those societies. Through the relatively new techniques of microbotanical and micro-wear analysis, I am able to access traces of many of the practices previously thought to be "invisible." This introduces a way to attend to those archaeological traces that are "hidden" but are also quite empirically identifiable material records of storage in, as well as on, the land. Through these traces we can in fact develop a picture of the diversity of ways in which early complex communities developed storage through their landscapes by preserving local niches and passing down pre-agricultural plant use practices. In attending to these strategies, we can start to understand what ancient communities sought to control, preserve, and/or modify through storage practices.

This dissertation's approach to storage further complements the work of scholars such as D'Altroy and Earle (1985), Blanton et al. (1996), and Adams (1981), who argue that although centralized control of resources is key in the emerging leadership hierarchies of early complex societies, the dynamics of newly institutionalized leaderships will vary greatly depending on the motivations of leaders and the kinds of resources upon which different economies rely. Staple crops (in the Mediterranean and coastal Levant, wheat, barley, and olive) have long been considered the key around which the early complex societies of Southwest Asia developed (Hastorf 1993; Philip 2001; Smith 2012). This dissertation doesn't dispute the value of staple crops, nor the intensification of their production in early complex Levantine societies, but rather asks that we expand our understanding of the ways in which the growing, processing, and managing of those crops is dependent upon a larger system of landscape management in which many other kinds of resources and values were stored.

Despite the significance of storage to most major interpretations of the development of ancient social complexity, as described above, there does not exist an extensive body of literature dealing with storage itself as a specific variable in ancient societies, or with its precise material record. Most detailed discussions of constructed storage compartments used to appear within isolated site reports (Sadori et al 2006; Bienniek and Pokorný 2005) or as one component in analyzing structural societal evolution, as described above (Nigro 2004). There are a series of articles, more recently, that consider storage comparatively within a micro-regional context

(Pfälzner 2002; Golani and Yannai 2016) or importantly, draw out the specifics of local storage practices in relation to larger regional models for social organization (Christakis 2004, 2008; Chesson and Goodale 2014). An important work taking on storage as its own kind of archaeological problem is Manzanilla and Rothman (2016), which brings together cross-cultural examples of storage technologies to think about the different ways in which storage developed, was materialized, and operated in relation to different cultural and administrative systems. Likewise, a recent Special Issue of Environmental Archaeology (Balbo 2015) also brought together a series of comparative storage studies. In both cases the authors and editors focused on relating on-site structures used to manage surplus foodstuffs to local political and structural conditions; while these studies are important, they tend to pay less attention to the broader landscape approach advocated here. There is nonetheless clearly a growing interest in unraveling the specifics of storage, that iconic symbol of complexity, and understanding the link between its micro-scale material manifestations and macro-scale socio-cultural effects.

This dissertation builds upon these important works and the attention paid to the role of storage in foundational anthropological and archaeological studies. In addition, it seeks to expand our understanding of what storage was, what it meant, and how it was practiced in a particular set of ancient societies, TFK and Sidon. Through this study, I intentionally expand the concept of storage beyond the bin itself – although bins and compartments are important to my argument, covered thoroughly in Chapter Four – to think about ways in which opportunities and authority are stored around, as well as within, the settlement itself, and how on-site storage construction depended on landscape storage strategies. These are the storage landscapes that I am interested in here – how new agricultural technologies were selectively taken up while extant techniques of wild plant exploitation were maintained.

I further suggest the idea that options for land use were being stored in the tools used for processing plants and other materials themselves – that the curation of parts of the land implies the ability to process its resources, and that that knowledge and variability is stored in the curation and management of ground stone tools over time.[2] While ground stone tools here provide but a brief case study for tool curation as part of a curated storage landscape, I propose that this could be expanded with further research to incorporate other kinds of artifacts in relation to this model.

In this approach, I am taking up the analytical category of storage in both its traditional role to designate the control of surplus food-stuffs (as above), and simultaneously expanding it to encompass the ways in which different parts of the landscape must be incorporated into a storage program that allows for the kinds of short and long term planning that such control requires. The botanical and the geological are actively and creatively engaged by past societies to store forms of knowledge, memories, and resources necessary to form the infrastructure of a complex and resilient administrative society – in this case, I will suggest, a network of such societies.

1.3 The Study Area: Early Bronze Age Lebanon

The place referred to as Early Bronze Age Lebanon is in practice constrained by contemporary country borders - and indeed, often even further constrained by political disputes along those borders (**FIGURE 1.2**). In concept, however, it remains a somewhat loosely defined place and time, as is of course the case for so many arbitrarily periodized segments of the past.

[2] It is certainly well-known by this point that ground stone/grinding tools were not exclusively used for processing botanical resources; this will be thoroughly examined and in fact is a central part of the argument of Chapter Five.

The chronology spans the late fourth millennium to the mid third millennium BCE, and is intended to demarcate the processes of settlement aggregation and nucleation, the transition to a reliance on staple crops, sustained by intensification and specialization of agricultural production (Hastorf 1993; Philip 2001; Smith 2012), the administration of these resources through centralized storage and redistribution (Genz 2003, de Miroschedji 2009; Chesson and Goodale 2014), and increases in social inequality linked to limited access to these goods at the group level (Chesson 2007, Harrison and Savage 2003; Nicolle and Braemer 2012). We know from the contemporary literature and the archaeological evidence that during this time, many settlements in the Levant developed a more tightly organized administrative elite who controlled the processes of agricultural production, labor, trade, and distribution (Ibid). Because these processes are closely linked to environmental conditions, the expansion and contraction of early urban settlements is often attributed to the optimization or failure of agricultural exploitation in the face of increased climatic variability of the Middle Holocene (Joffe 1993; Roberts et al. 2011; White et al. 2014; Weiss 1993; Weiss et al. 2000, 2010).

Besides climate change, researchers have in the past focused on external catalysts for settlement contraction, such as migration and/or invasion (Hennessy 1967; Lapp 1970), or interpretations of derivative influence, based on contact with and observation of earlier, larger-scale settlement developments in Mesopotamia and Egypt (Esse 1989, 1991; Campbell 2000 describes this problem for western Syria generally). Alternatively, “indigenous evolution” has been argued (Schaub 1982; Miroschedji 1989; Joffe 1991), which productively asserts the unique local expressions of social complexity in the Levant, but nonetheless assumes a uni-directional trajectory for settlement development that the Levantine settlements are on, albeit at a different pace. Despite all the sophisticated archaeological work on complexity that has emerged over the past several decades, it is still not uncommon to find settlements assessed based on attributes associated with evolutionary stages of complexity, such as walls, monumental structures, writing, etc. (See Chesson and Philip 2003 for further discussion).

An alternative coming from work in the Southern Levant, (modern Palestine, Israel, and Jordan), Timothy Harrison makes the persuasive argument that Early Bronze Age settlements, as they become more complex, must be analyzed according to their relationships to each other, rather than by quantifying internal attributes of complexity at each settlement. He suggests that assessment of their "integration [within a regional network] rather than [individual] scale," should be developed as a better analytic of complexity (Harrison 2003: 33). In the same special issue of the Journal of Mediterranean Archaeology, focused on the EBA of the Southern Levant, Graham Philip reminds us that settlements develop across landscapes which are made up of values and meanings often constituted and changed through daily practices, something that must be analyzed again with a relational sensibility – how do the interactions of people with their places leave traces that inform sets of appropriate behaviors, that themselves become part of the way social complexity emerges (Philip 2003)? He finds that new agricultural technologies for staple crop production produced an "EBA economy [that] offered new routes to power that were underpinned by access to land," and that "many aspects of the modified landscape of the EBA reflect the material expression of just such power" (Philip 2003: 123). He calls on researchers to develop local understandings of the ways in which landscapes are modified in relation to the development of other kinds of archaeological traces that might have been more compelling to early archaeology, such as monumentality.

These are important concepts that this dissertation applies to the study of the northern EBA Levant through its two case studies. The southern Levant certainly has been far more extensively studied, and therefore offers more detailed data for immediate analysis in terms of relational settlement developments, but this project contends that we must take an integrated landscape approach to studying the emergence of local complexity from the start, to develop better models that do not depend on external influence or anticipated trajectories. Thinking of complexity through the lens of storage in, through, and of the landscape is an attempt to theorize the sets of relationships of people to place and to each other that locally and specifically contributed to the way these EBA complex settlements emerged in coastal Lebanon.

1.3.1 Middle Holocene Environmental Conditions and Geomorphology in Lebanon

The Early Bronze Age (c. 3900-2400 BCE) falls within the Middle Holocene (c. 5000-2000 BCE, after Rosen 2007), which is characterized both by the rise of complex societies throughout the Levant, and by much greater climatic variation between wet and dry phases than immediately previous or subsequent periods. Alongside intensified anthropogenic landscape modification, such climate variability affects vegetation distribution, and characteristics of the landscape like soil erosion and viability (Riehl et al 2014; Bar-Matthews et al 1999). The mid-late third millennium BCE is a period of particularly marked debate in the archaeological literature on early Levantine urbanism, as it is characterized by a major regional arid episode, known as the "4.2k" event, and coincides with some – but not all – decentralization movements in the region, although Lebanon appears to be minimally affected (Ristvet and Weiss 2005, 2011; Staubwasser and Weiss 2006; Riehl 2008, Riehl et al 2014).

The coastal Levant – the coastal area of Southwest Asia including Israel, Palestine, northern coastal Syria and modern Lebanon - is largely influenced by the Mediterranean climate system, which lies in the transition zone between the Westerlies low-pressure system to the north and the Azores high-pressure zone of the subtropics to the south. The south-moving Westerlies system brings with it the rainy, low-pressure depressions of winter, which increases humidity along the south and southeastern regions of the Mediterranean coast. In summer, the high-pressure belt moves north, increasing temperatures and aridity (Issar 2008; Issar and Zohar 2004). The movement rate of the belts southwestward can vary greatly, and thus so can annual rainfall, which in turn affects the viability of annual farming ventures.

Lebanese biodiversity is among the richest in the world; Lebanon occupies only 0.007 % of the world's land surface area and is a home to 1.11% of the world's plant species and 2.63% of the reptile, bird and mammal species. As of 2009, there were 9,119 identified terrestrial species, of which 4,633 are plants and 4,486 animals (Convention on Biological Diversity 2009, 11). Floristic richness is estimated to include 2,600 vascular plant species of which some 400 are endemic to Lebanon, Syria and Palestine (15%) and at least 92 are endemic to Lebanon (3. 5%) (Ibid, 11, 25).

The distinctive and restricted geomorphology of Lebanon provides a unique opportunity to investigate the reaction of early complex societies to climate variability in relation to their micro-environments and their geo-political orientations (Marfoe 1998; Rosen 2007; Genz 2012b). The geographically restricted area comprising modern Lebanon offered benefits and challenges to emergent complex societies that were very different from those afforded by more extensively studied neighboring areas in the region. In Lebanon, two mountain ranges and the elevated Biq'a Valley run along the east above a narrow coastal strip in the west, dictating a north-south orientation for transit and settlement development along the coast **(Figures 1.3, 1.4).** Water in Lebanon was plentiful due to high rainfall and natural reservoir systems, but arable land spaces were extremely restricted between narrow and diverse ecological biomes (Riehl et al 2008, 2014; **Figure 1.5**). The north is the more dramatically variable and steeply mountainous, with both the widest and narrowest points on the coastal plain (the Akkar and Ras Chekka, respectively), whereas the southern coast broadens steadily as mountains gradually decline and recede into the foothills of the Galilee.

Along the narrow northern coastal plain and foothills, the current vegetation is dominated by maquis shrubland, and includes representatives from the genera *Juniperus*, *Myrtus*, *Olea*, *Pistacia*, and *Quercus* (primarily *Q. deciduous* and *ithaburensis*). Today, much of the maquis coverage on the foothills is degraded into guarrigue and batha. In the north, where the coastal plain expands, citrus is now cultivated, while other Mediterranean fruits such as *Ficus carica, Punica granatum, Olea europea* and *Vitis vinifera* occur frequently. The western slopes of the Lebanon Mountains retain remnants of pine forest (*Pinus halepensis* and *P. brutia)* up to 1200 m., at which point the former forests of *P. nigra*, *Cedrus libani*, and *Q. calliprinos* have been reduced to less than 5% of their original extent (Scott 1995; **Figure 1.6**).

1.3.2 Regional Settlement Patterns

Local EBA settlement patterns present another point of distinction within regional urban developments. In better known neighboring areas, such as Mesopotamia and Egypt, the organizational stresses of population increase and climate flux resulted in large-scale, highly centralized urban centers that controlled the resources of an even larger rural hinterland (Schwartz et al 2006; Stein and Rothman 1994; Patch 1991). In Lebanon, however, early aggregated settlements developed as a closely linked network of much smaller-scale, densely occupied sites within restricted territorial and ecological niches (Marfoe 1995, 1998; Genz 2012b). While this difference has been noted at the regional survey level (Philip and Williams-Thorpe 2001; Marfoe 1979, 1995, 1998), little research has been done in Lebanon on the precise history of aggregation and complexity, or the range of technical behaviors through which early aggregated societies engaged with their local environments, with climate variability, and with each other.

Since early prehistory, the Levant has served as an important zone of mobility and interaction between societies throughout the Middle East, North Africa, and later the Mediterranean (Derricourt 2005). By the late fourth millennium BCE, Levantine settlements were very different in the north and the south. In the Southern Levant, scattered villages and semi-mobile populations started to aggregate into substantial nucleated settlements, sometimes up to 30 hectares, quite early (Schwartz et al 2006; Stein and Rothman 1994). Significant late Predynastic/early Dynastic Egyptian presence is clearly evidenced (Wengrow 2006; Yekutieli 2004; Steiner and Killibrew 2013), but by the end of the EBI (c. 3000 BCE), the Egyptians largely withdrew, and settlements were reorganized into nucleated, walled towns independent from Egyptian power or administration (Joffe 1993). Planned, nucleated and often walled settlements with more recognizable patterns of regionalization in material culture then emerged, but by the mid third millennium, a pattern of de-centralization and return to wide-scale pastoralism is widespread (Philip 2003; Chesson and Philip 2003; Greenberg 2002, 2003; De Miroschedji 1989).

In the north, much less information is available, as research has been limited due to modern conflict. However, it is clear that the Uruk period “colonies” of the early fourth millennium disappeared by the EBI and had little effect on subsequent settlement development

(Genz 2012b; Thalmann 2006; Cooper 2006). Some small villages were already present, including a partially walled village at Sidon Dakerman (Saidah 1979) and a group of similarly constructed mono-cellular buildings at Byblos (Dunand 1973). At Byblos, there appears to be a progression from oval to rectangular shaped buildings, suggesting possible sub-phases in this period of occupation (the Énéolithique Récent of its excavator, M. Dunand). EBI jar burials at Byblos likewise show a variation between those with dense, valuable grave goods and those without, indicating that even at this stage, some degree of social stratification was emergent (Artin 2005; Genz 2014). At Sidon, some small-scale EBI/Chalcolithic occupation is attested but with very limited extent, leaving a working theory that primary occupation during this period primary settlement was at the Sidon Dakerman site just to the south. At TFK, there is likewise limited available archaeological evidence from the EBI/Chalcolithic, although this may be due to the extensive overlying EBII-III architecture that cannot be moved, as two jar burials and an assemblage of hand-made EBI pottery including one with a cylinder seal impression have been found in the limited area of exposure alone (Genz and Mardini 2017; Genz 2012). Even these limited results may indicate a scenario in which the EBI/Chalcolithic in Lebanon that is tending towards small groups of small-scale, gradually aggregating sites quite close together, and beginning to develop the material trappings of ranked stratified societies.

In the EBII, populations shifted toward fewer but more densely aggregated settlements, an increasing number of which were walled (Lauffray 2008; Cooper 2006). Craft specialization and a mixed subsistence economy that show indications of regionalization seem to have intensified as well (Mazzoni 2004; Genz 2009, 2012). The EBIII saw further expansion at both TFK and Sidon, with the construction of new large, central buildings at both sites (further discussed in Chapters Two and Four). Preliminary results at Tell Koubba, 1 km north of TFK, indicate a similar chronology. Byblos, which will be discussed in depth in the following chapter, emerged by the beginning of the third millennium BCE as one of the largest (relatively speaking of course, at around 5 hectares) and most internally complex settlements in the vicinity, with clear established connections with Egypt (Dunand 1973; Saghieh 1983; Nigro 2007). Together, these suggest the kind of network-oriented settlement patterning that Harrison advocates as a driving analytic for local complexity, and that Marfoe identified at the survey level for the Biq'a. Importantly, Tell Arqa shows a similar pattern of increasing settlement density and expansion at this time, and survey of the surrounding Akkar Plain – the alluvial outlet of the Homs Gap, the northern passage from the Biq'a Valley down to the coast – has indicated that a dense network of small-scale but roughly hierarchically arranged settlements also emerged very rapidly in the early-mid third millennium BCE (Thalmann 2010, 2016).

The largest documented EBA settlements in Lebanon, Byblos and Tell Arqa[3], never exceeded 5 and 7 hectares, respectively, a fraction of the size of contemporary settlements in neighboring regions. In sum, Lebanese early aggregated sites show evidence of organization in relation to a particularly fragmented landscape of rapid topographical change and dramatic ecological diversity within a very small geographic space (Marfoe 1995, 1998; Badreshany 2013). EBA settlements were made up of networks of small, very dense walled towns that had to be organized differently than those located in the more open and arid landscapes of regional neighbors (Marfoe 1998; Genz 2012b). While outside texts and local cylinder seals refer to local elite administrators (sometimes referred to as "mayors" (Montet 1921; Bietak 1991) and

[3] Sidon was almost certainly a similar size to these sites, but as it cannot be properly exposed due to the modern city directly on top of it, it is not definitively included here.

associated administrative councils, these appear to have been unique to major settlements along the coast which controlled only restricted local territories.

Such settlements are particularly susceptible to the effects of settlement expansion and landscape modification, which is both an ancient and modern problem (Makhzoumi et al 2012, Radford et al 2011). Indeed, sites in neither the northern nor southern Levant can be said to have been permanently occupied throughout the course of the EBA. In fact, most excavated settlements show intermittent brief occupational hiatuses (for instance, Bet Shean, Megiddo, Tell Arqa: Thalmann 2010; Greenberg 2003; Höflmayer et al 2014), sometimes accompanied by spatial reorganization but continuity in material culture (Greenberg 2003; Savage et al 2007). Previously, these contractions and expansions of settlements have been perceived as the fits and starts of new, experimental socio-political complexity – the markers of a pendulum swing between success and failure as populations adjust to managing their new grain agriculture-based communities.

The results of this dissertation suggest that this interpretation has merit but requires further thinking about how that played out in terms of technical practices associated with grain agriculture. The highly variable northern Levantine environment necessitated flexibility in subsistence strategies and modes of production (Marfoe 1995, Badreshany 2013). Leon Marfoe's concept of the pastoral-urban continuum as opposed to an urban political unit bounded by its relation to a non-urban hinterland, describes one way in which the unique geographic nature of Lebanon was conducive to small-scale settlement organization within a complex and resilient political context (Marfoe 1978, 1995, 1998). He argues that patterns sometimes perceived as "collapse," may be understood as the outcome of centrifugal tendencies of small-scale settlement flexibility, characterized by intra-site cooperation to navigate a uniquely diverse environment (Ibid. 1998, 238).

This model could only be further confirmed by regional survey, which was denied to the author at the time of this dissertation project proposal by local authorities, but which is currently being undertaken by several new projects that will hopefully expand our understanding of settlement distributions over the landscape. In the meantime, the material and technical characteristics of the flexibility of and between settlement patterns, as suggested by Marfoe, can be tentatively modeled through the direct evidence for plant use and processing technologies in relation to environmental and political change at the sites in question. I suggest – preliminarily – that we consider variations in settlement and landscape use not just as special characteristics necessitated by a restricted geomorphological settlement area, but as part of long-term resilience strategies that actively incorporated the storage of possibilities for variable plant use in their curation of their local wetland niches. Alternatively, these niches may have continued to be available due to the relatively high precipitation rates in coastal Lebanon and the absence of large scale development that would damage them, and therefore were available for exploitation alongside the new cereal crops. Either way, through the continued use of wetland plants alongside agricultural cereals, these early small-scale aggregated societies were better able to navigate the variability of Early Bronze Age weather and climate patterns, and adjust to socio-political transformations affecting the region.

1.3.3 The Northern Case Study: Tell Fadous-Kfarabida (TFK)

TFK offers a rare opportunity to investigate an EBA settlement relatively undisturbed by later occupation, at least in the sense that there is no later construction on top of the Bronze Age settlement remains (Genz and Sader 2008; Genz et al. 2009, 2010). The sit is located 2 km south of Batroun and 12 km north of Byblos, on an alluvial fan directly on the north-central Lebanese coast. The settlement was probably originally 1.5 hectares, although much of it has been destroyed by bulldozing prior to archaeological investigation (**Figures 1.7, 1.8**).

Excavations have revealed only limited, fragile and fragmented architectural remains and two jar burials from the EBI (beginning c. 3200 BCE) (Genz et al 2009). After an occupation hiatus of no more than a couple of hundred years, the site was rapidly reoccupied around 3000 BCE, when dense, multi-roomed residential structures appear separated by narrow, planned streets; limestone column bases inside the rooms likely supported wooden columns and upper stories, as attested in one room by the conflagration of a wood-beamed roof (Genz et al 2009, 2010, 2011, Genz 2012a).

The site continued to grow and transform over two phases in the third millennium. First, the domestic architecture expanded and grew into two-story structures and a fortification wall was built around the settlement. Monumental public architecture then replaced some residential buildings, and expanded directly upon other lower structures. The presence of locally produced cylinder seals with parallels to Byblos evidences a linked administrative presence (Genz 2012a). TFK during this time was around 1.5 hectares, making it a medium-small but dense settlement for the area. Around 2500 BCE, it appears to have been largely abandoned in terms of year-round occupation; after a brief hiatus, only pits and eventually, in the MBA, burials are found. This change of site use roughly coincides with similar settlement contraction movements in the Levant, which, as discussed above, have traditionally been linked to 4.2k "drought" event (Ristvet and Weiss 2011, Staubwasser and Weiss 2006). However, the new dating of this contraction process at TFK clearly places it centuries before the earliest affective range of the

4.2k event (Höflmayer et al 2014). Settlement transformation therefore requires a different explanation and supports a renewed attention to the details of environmental and technological adaptations in this area.

Previous analyses of excavated material show a range of plant processing and use. Domestic cooking vessels, drinking cups, and storage vessels have been recovered alongside "special" meals marked by fine ware vessels and large amounts of animal bones. Notably, drinking vessels are found in the earlier levels alongside platters for solid foods, while the latter do not become significant in the southern Levant until the later third millennium (Genz 2012a; Bunimovitz and Greenberg 2004). Pits from later phases also contain ceramics and flora/fauna remains possibly consistent with feasting episodes (discussed in more detail in Chapter Four), showing that food practices were significant on the site even after year-round occupation changed in density and overall character of living (Genz 2012a). The general macrobotanical assemblage suggests an agricultural economy oriented towards specialized production of wheat and olive (Riehl in Genz et al 2009 and 2014). The new microbotanical evidence presented here demonstrates that while wheat was clearly in specialized production over the long term at TFK, wetland taxa are critical to its success as an economic crop (described in Chapter Four).

1.3.4 The Southern Case Study: Sidon

Sidon, 20 km south of the modern capital of Lebanon, Beirut, is known from later Babylonian, Greek and Egyptian texts as one of the most important sites of the Levantine littoral during the Bronze Ages. It is situated in an area where the coastal plain begins to widen into the more temperate, gradually rolling hill country of the southern Levant. Because the city has been continuously occupied until the present day, researchers have had to be creative in their approaches to understanding its history; until the 1960s, most information was inferred from the nearby sites of of Bostan-esh-Sheikh (the temple complex of Eshmun, the healing god) and various necropoli reported by 19th century officials. In the 1960s, the Lebanese Directorate General of Antiquities was able to acquire three land areas on the ancient tell of central Sidon, in the vicinity of the medieval "land castle" or Castle of Saint Louis (Doumet-Serhal 2004). The area around the castle had already been partially excavated in the 1910s by the French archaeologist Georges Contenau, but work on the main areas under consideration here, to the east and north of the castle, were only taken up in 1969 by Maurice Dunand (also famous for the excavation of Byblos, in the north). Continuous occupation sequences down through the EBA were discovered in a 1970s *sondage* by Patricia Bikai.

The EBA areas in the College Site and Dunand Site that furnished the data studied here were intiiated by Dr. Claude Doumet-Serhal, with permission of the DGA, in 1998 and continue to this day. Based on these excavations, six "strata" of Early Bronze Age occupation have been identified (**Figures 1.9, 1.10**), sometimes including within them several phases. Settlement at Sidon appears to have emerged as an early Chalcolithic village site associated with another site one kilmoeter to the south known as Sidon Dakerman. The latter disappears at the end of the EBI, and the central site at Sidon, after a brief occupation hiatus[4], becomes more densely consolidated into a planned town center (late fourth millennium BCE; Hours 1979, Doumet-Serhal 2006).

[4] The 2004 publication, and subsequent articles, state that there was no break in occupation for the entirety of the Early Bronze Age at Sidon; however, description of the stratigraphy shows a featureless level of beach sand in between the EBI and EBII levels, which seems to at least designate a transitional period, if indeed a short one.

EBII-III Sidon follows the familiar pattern of rectangular, multi-roomed domestic architecture aligned with perpendicular streets. Buildings also typically had two stories supported by wooden columns on limestone bases, although the main architecture here was constructed in mudbrick rather than limestone (similar to Tell Arqa in the far north, but contrary to the north-central stone architecture seen at Byblos and TFK). Particularly significant is a large mudbrick building with multiple storage compartments that was catastrophically burnt at the end of the third millennium BCE. Strong trade connections with Egypt and the Southern Levant are attested by the ceramic and chipped stone finds, but cylinder seal impressions on vessel fragments have their best parallels at Byblos (Doumet-Serhal 2004; Genz 2012b). The excavators argue that despite the destruction of the mud brick storage complex, there was no other interruption in settlement at the end of the third millennium BCE, leading them to suggest that the "EBIV," as a transitional phase leading into the second millennium and the Middle Bronze Age, did not exist as as separate phase at this site (Doumet-Serhal 2006).

From the macrobotanical evidence, Sidon's agricultural economy seems similarly to have been focused on wheat and olive surplus cultivation, as well as an overwhelming concentration of two-rowed barley from the mud brick storage building, but with a wider exploitation of grapes and figs also present (de Moulins 2009). Feasting or otherwise exceptional consumption is indicated both in ceramic deposits and by butchered large game species such as hippopotamus, aurochs, and boars. This is also a significant contrast to the faunal results at TFK, where only limited hunting is attested (Vila in Doumet-Serhal 2006). The microbotanical results indicate that Sidon heavily employed wild grasses, as well, and also relied on wetland taxa to maintain the structures that supported this kind of agricultural surplus and hunting regime.

1.3.5 The Comparative Approach

Comparatively, then, both sites offer evidence of multiple phases of occupation during the EBA; however, while settlement at Sidon faced only a minor interference at the end of the third millennium BCE, TFK appears to have experienced a significant contraction and reorganization of settlement use (Doumet-Serhal 2006; Genz 2012b). Nonetheless, TFK's settlement contraction cannot be related directly to climate crisis, as the final de-urbanization of the site occurs several hundred years before the "4.2k event," and the resilience of Sidon immediately following this period indicates that its political trajectory was not substantially affected in the long-term (Höflmayer et al 2014). Indeed, barley isotopes indicate little evidence for severe moisture deprivation throughout coastal Lebanon during this time (Riehl et al. 2014).

The macro-botanical data at both sites indicate an intensification and specialization of surplus staple crop production (wheat and olive, and barley at Sidon) within an otherwise broad spectrum plant economy at the beginning of the EBA (Riehl and Cakliklar in Genz 2009, de Moulins 2009). While these crops were certainly produced at a surplus level, above the subsistence needs of each site, there is no evidence for large-scale Levantine exports of grain or olive in neighboring regions, so they appear to be oriented towards regionally local, intra-site consumption (Genz 2003; de Moulins 2009; Riehl et al. 2014). However, the botanical remains at both sites only reflect a partial record of plant use, as preservation conditions are not ideal throughout all occupation phases, and even in the best circumstances, macrobotanical remains generally depend on contact with fire before deposition, thereby excluding parts of plants that are discarded during processing stages. Analyses of the microbotanical remains (which have their own limitations, discussed below) in this dissertation demonstrate that a far wider range of wetland resources were equally important to the maintenance and development of these settlements as the more frequently studied staple crops.

Grinding equipment at each site is also different: at TFK, over 70% of the assemblage is made of local, expediently manufactured limestone with an emphasis on small and reused grinding tools and a wide range of mortars, whereas in Sidon nearly 90% of the assemblage is made of non-local, moderately well manufactured basalt, with an even distribution between large grinding slabs/handstones and very few mortars (Figure 7; Damick 2009; Doumet-Serhal 2006; personal observation of material). This is the first time that any use wear study has been conducted on the grinding tools from these sites; while this is limited here to a case study of preliminary observations from ten stones from each site, it indicates great potential to expand our understanding of the way work upon the land extends into the practices and materials of work within the site, and how land-based knowledge is stored in multiple forms. Further work will situate them contextually within broader changes in the environment and regional settlement patterning.

Scholars of early sedentism have frequently discussed the ambivalence that mobile and semi-mobile hunter-gatherers and pastoralists must have felt towards becoming primarily sedentary, how it must have introduced great risk to well-being and disrupted established relations with the landscape and with other people (Ingold 2000; Maher 2010; Rosen and Rivera-Collazo 2012). Archaeologists have frequently problematized the transition from types of subsistence behaviors among so-called simple societies; however, once a society has become predominantly sedentary and socio-politically complex, it is more frequently treated as if that growth and expansion do not pose the same kinds of existential and technological problems. The "risk" can sometimes appear to be a loss of sedentism, a "return" to non-sedentary living, despite plenty of ethnographic evidence demonstrating that such linearity and order of progression is by no means universal. I would like to perhaps engage more fully with the lessons of hunter-gatherer research, which clearly teach us that societal developments are neither linear nor teleological, but rather a series of negotiations between the known and the unknown to adapt to new circumstances as they arise. Movement between foraging and agricultural techniques should be seen as a set of strategies not all that unusual and certainly not antithetical to socio-political transformation.

The evidence from micro-botanical and ground stone technology at these early complex aggregated sites in Lebanon illustrates this point. There were pushes in some areas towards new infrastructures, aesthetics, and economic symbols and practices, such as the construction of large public building 4 at TFK and the mud brick building at Sidon, both including large-scale storage constructions and the proliferation of cylinder seals and the use of their impressions[5]. In other areas, there was instead a conservatism that actively worked to maintain smaller-scale techniques even when it was not necessarily the most efficient or convenient choice, and certainly wasn't the one most likely to lend itself to territorial or economic expansion, such as in the continued reliance on certain wetland plants or the continued use of coastal limestone and sandstone even when basalt became readily available (Damick in Genz et al 2015).[6]

At TFK, the maintenance of small-scale ecological niches within larger farming areas may suggest risk mitigation intended to function at the micro-regional level and allow for

[5] There is much debate, of course, over what cylinder seals were actually used for; this is beyond the scope of this project, but see Wengrow 2016b and Mazzoni 2018 for further discussion.
[6] In fact, the Ugaritic term ýbn, "stone" (KTU 1.3 iii 23; 1.82,43, etc.) is connected to the Semitic cognate bnw.t, "hard sandstone,." all from Afro-Asiatic *b-n, "grinding stone", as proposed by Takács (EDE II, 213)8. This indicates a profound connection to local stone, demonstrably less efficient than basalt for its task, over a long period of time.

periodic settlement dispersal. Alternatively, it may serve as part of a larger system of small administrative settlements designated to support emergent central organization at larger sites like nearby Byblos. Similarly, the option to curate particular kinds of lithic technologies when others were available may speak to a focus on household-based subsistence and mobility, rather than the delegation of these practices to large-scale specialist groups and entrenchment of ranked, coordinated hierarchical control over those products, such as is seen in the large processing rooms at Ebla (Peyronel et al 2014). Alternatively, the fragmentation in the record may be a function of taphonomy and preservation.

At Sidon, we see a slightly different situation, in the presence of generally larger tools that have not been extensively curated over time, selected for their non-local raw material, and used in a more specialized capacity. While we still see the curation of local ecological niches in the wetland taxa apparent in the phytolith analyses, these appear more likely to be built around sustaining the specialized needs of a more highly-ranked settlement that transitioned quite differently into the second millennium BCE than did the smaller settlement at TFK. While Sidon was certainly more palatial than TFK, I ultimately suggest that we think of it in the sense suggested for the Aegean by Christakis (2008) – as more of a large estate than a truly redistributive palace economy, as will be further elaborated in Chapters Four, Five, and Six. While at TFK the population de-centralized and reorganized several times during the EBA, Sidon transitioned into the kind of wealth-mobilizing but only self-sustaining center that characterizes the Levantine Middle Bronze Age.

I will suggest the possibility that the Lebanese EBA polities, far from being peripheral to and/or imitative of Mesopotamian and Egyptian large-scale societies of the time, worked as small-scale networked entities in relation to the diverse landscape in ways that preserved that diversity, and therefore preserved possibilities besides centralized administration of grain agriculture for their communities to live in relation to each other and to political processes going on around them. We should consider that these two sites represent different settlement roles within a networked coastal economy, and that Sidon may tell us more about what Byblos was in relation to TFK, while TFK may tell us what kind of extra-settlement support Sidon operated with. In this interpretation, landscape and plant use became infrastructural themselves, in their preservation of possibility for mobility and provision from multiple sources depending on the goals of local leadership within a larger network. At TFK we see the former emphasized, and at Sidon, the latter.

The environmental choices these societies were making were of course also undertaken in relation to changing climate patterns, even if these were less strongly felt in Lebanon than elsewhere in the region. In an influential paper in 1995, Arlene Rosen followed up on the suggestions of earlier researchers that we should change our research questions from those focusing on which climatic patterns caused societies to fail, and start asking instead why some societies are less adaptive to environmental change than others (De Vries 1980; Rosen 1995). She used phytoliths and geomorphological data to demonstrate that while centralized control of surplus by a managerial elite in the EBA Southern Levant was a good short-term strategy, it prevented the continuation of previously successful long-term responses by subsistence farmers, ultimately resulting in a failure of the centralized systems. This dissertation builds on that essential premise, suggesting that in the case of the Lebanese EBA settlements, balance between centralized organization of agriculture and use of longer-term wild plant use practices may be indicated. This balance was itself one of several strategies to maintain local settlement control and resilience within their general territory. Seen in that light, what was “at risk” was not (yet) the collapse of a centralized polity that might develop into a powerful city-state, but rather the ability to a) survive and feed the community, and b) maintain important social and political functions, and therefore the communal fabric that held the system together in the first place. To mitigate risk to that fabric and the economies that supported these settlements (primarily agricultural and pastoral), various strategies and technologization of the environment were undertaken to produce a heterogeneous, complex landscape with diverse settlement options and opportunities. This is what I call the EBA storage landscape; it is preliminary and tentative, but a suggestion of a research direction for the future as landscape archaeology expands in Lebanon for the first time in decades.

1.4 The Data: The Persistence of Micro-Worlds and 'Trace-ology'

This dissertation uses microbotanical and microscopic use wear analysis to describe the ways in which plants and stones were being cultivated, procured, used, and curated by the populations of TFK and Sidon during the Early Bronze Age. Through these microscopic data sets, we can see how those use processes continuously engaged in microscopic surface modifications that ultimately had long-term effects on the land and the people using them.

The primary way in which people experience their worlds and interact with them, making strategic choices or improvisational gestures, is through surface encounters. Surfaces, conceived of as multi-scalar processes, gatherings of the micro-organisms, particles, and chemical and biotic reactions into an interface with the human senses, are (fortunately for the archaeologist) frequently marked by past human encounters in such a way that persists over very long time periods. We are only beginning to scratch the methodological surface of how to access and understand these traces archaeologically.

Proposing “surfaces” as an analytic entryway into micro-traces may seem to raise the specter of privileging the visual in the archaeological record, of approaching the past as a series of vast textures and objects laid across a consistent underlying substrata, an issue that has long been critiqued in landscape survey approaches (Bender 1993). However, I follow Graves-Brown (2010) in considering the way in which surfaces emerge from the inside out and become constitutive upon encounter, although the microscopic, long-term cumulative effects of that encounter may not be visible for millennia, if ever.

Humans don’t often think of the material impacts that they have on the world if they can’t see them. The idiom “out of sight, out of mind” is a common one across many languages (the Arabic goes: “بعيد عن العين، بعيد عن القلب,” or “ba'eedun 'an il-'ayn, ba'eedun 'an il-qalb,” meaning “far from the eye, far from the heart”), in practice we know this is not always the case. Typically, this phrase is meant to refer to psychological impact of human separation, of course. But it is relevant to my consideration here of the invisible or unseen impacts of encounters of the material world, as well. The micro-transformations of material-on-material contact (from minerals and water, to plant on plaster, to human thumb on stone) that have very real material consequences too. Archaeology has increasingly developed the tools to access and theorize these encounters; indeed, it is such material and affective consequences that we can thank for the scientific identification of phytoliths.

1.4.1 Phytoliths

Phytoliths are siliceous casts of plant cells formed by many plants during their life-cycles (**Figure 1.11**). Plants take up silica in the form of mono-silicic acid from groundwater, and when the water is broken down and released through evapo-transpiration, that silica is left behind deposited in the cell structures of the plant. This silica builds up over time at different rates in different parts of the plant, and the siliceous casts of the plant cells are then deposited upon degradation of the organic plant body in the sediment: these are phytoliths that can then be extracted from the sediment where they decayed. Their analysis therefore provides an advantageous complement to more widespread macro-botanical analyses, as phytoliths do not depend on contact with fire for their preservation archaeologically. Phytolith analysis has been used archaeologically to reconstruct a wide range of plant uses in the past, from agricultural economies (Rosen and Weiner 1994; Piperno 2006; Jones and Liu 2009) to direct evidence for diet (Henry and Piperno 2008) to social plant uses such as floral burial deposits (Nadel et al 2013). Multi-cell phytoliths from the husks of domestic cereals have been used to make identifications to genus and even species (Rosen 1992). Because phytoliths are formed via evapo-transpiration, and therefore depend on conditions of soil, drainage, and water, recent studies have proposed that they may provide indirect evidence for agricultural land use, substantiated by the observation of differences in cereal husk phytoliths according to local environmental factors (Rosen and Weiner 1994; Mithen et al. 2008; Katz et al 2013).

Once deposited in sediment, phytoliths are fairly stable as long as the sediment remains so, but once that sediment is transported, they can be carried with it, depending on the strength of the transporting force. This happens, for instance, in windswept dusts from the deserts or large erosional landscapes. In one such instance two hundred years ago, a particular collection of phytoliths were carried on a particular set of winds off the African coast of the Atlantic in such great numbers that they thoroughly clogged, scratched, and damaged much of the navigational equipment and scratched some of the sailing structures on board the *HMS Beagle*, currently attended by one Charles Darwin (Powers 1992). This caused a certain amount of frustration and consternation on board among crew members. Darwin investigated and collected some of the offending particles, and sent some samples to his colleague Charles Ehrenberg, who had previously worked to identify the micro-structures making up similar dust on his trips throughout Egypt and the Sudan. Ehrenberg found that the majority could be classified as "Phytolitharia," taking the combination of the ancient Greek for "plant," ("phyto") and "stone" ("lithos") to create a new sub-classification of "Infusaria," which at the time described various micro-organizations such as foraminifera, protozoa, etc.[7] In this sense, one could say that these microscopic plant-stones forced their presence onto scientists via their material and technological impact, their disruption of working systems that did not take them into account.

We now understand phytoliths far better, of course, although researchers are still working on the best practices for processing, identifying, and comparing them globally (Piperno 2006; Ball et al 2016; Pearsall 2018). Increasing research on phytolith analysis not only allows analysts to identify, under high-powered microscopy, what kind of plant was present in a given place, but what parts of different plants were deposited in different places. For this reason, they are very useful for tracing plant processing pathways and locating plant types and parts that are not generally preserved macro-botanically. The precision recognition of phytoliths is such that identification below the genus level is not very frequent, except in specific cases. We therefore cannot hope, for instance, to identify all the wild grasses or shrubs present along the coastal

[7] Piperno 2006

slopes of Lebanon, but we can determine the family or genus of the plants, which can be indicative of either wild or domesticated grasses or shrubby taxa, or which can tell us about the type of micro-environments present and what type of plants they hosted. We can also identify the frequency of different parts of those plants and change of those ratios over time, which tells us about anthropogenic management of those environments. **To this end, 70 sediment samples from TFK and 30 sediment samples from Sidon have been analyzed for phytolith content.**

1.4.2 Ground Stone Use Wear

The discovery and study of stone micro-traces has a similar origin story, thematically. Although S.A. Seminov is the true "father" of archaeological stone use wear studies, and will be discussed further in the following chapter, subtle traces of different kinds of friction on varying material surfaces begins with another illustrious but perhaps unexpected historical figure: Leonardo da Vinci. Da Vinci wrote in his journals about distinguishing friction patterns based on the weight applied to and the relative smoothness of surfaces in contact in 1493 and pursued this principle in his studies of mechanical properties for over twenty years (Hutchings 2016). However, because his findings were never published, it was only centuries later that the principles he'd discovered were made more widely known by two French researchers, Guillaume Amontons and Gustav Auguste Colombe (Ibid). In all cases, however, these early studies were designed as engineering problems, to address mechanical difficulties and increase machine efficiency by examining how surfaces in contact effected each other, and could through modification be made more efficient and productive; in other words, how to minimize the degree to which materials acted back against the intent of the machine and its makers. Although the various kinds of frictional traces could not be seen (including tribochemical, aggradation, deformation, and adhesion, to be discussed further in Chapter Two) until the invention of much higher-powered microscopes in the twentieth century, they came to the attention of scientists once again because they "got in the way" of other processes.

In observing the way in which these micro-traces came to the attention of European scholarship through their capacity to intervene, our attention must be drawn to considering how they must also have shaped and acted back on human and non-human worlds throughout history and prehistory. In analyzing the micro-traces of plant technologies, I think not only about what they tell us about the components of said technologies but also about how the accretion and dissemination of the traces themselves must have intervened in and therefore helped to shape the lives and labors of those engaged in producing them. Technologies of the past, be they mechanical or agricultural, cannot be separated from the invisible imprints that their activity makes on society and the environment, and indeed their development must in some ways be seen in relation to the way those traces that intervened in technological processes. In this way, we must understand that surfaces of encounter in technological processes are by no means static but are themselves constantly in states of emergence (Gibson 1979). There is perhaps not such a firm distinction between the surface and the substance underneath (Graves-Brown 2010).

By studying the way in which multiple kinds of emergent micro-traces come together in technological encounters over time (what Brian Boyd calls "micro-histories," Boyd 2017), we can begin to think in more attentive ways about the decisions and behaviors of people engaging with those surfaces. Therefore, a general overview of the ground stone assemblages at each site are presented to trace the geological zones in use for the tools of daily life, and **10 grinding**

stones from TFK and 10 grinding stones from Sidon have been analyzed for use wear traces.[8]

In particular, this dissertation is interested in the technologies of storage through landscape use – how plants and stones were cultivated, collected and processed over time, and how those particular affordances of the land are indicated through plant use. This project posits that micro-traces of past human-plant technical behaviors serve as both an important analytical tool, but also must themselves be thought materially, as artifacts that both influenced larger patterns of social activity and express that activity archaeologically. Human choices about intervention in a landscape is partly related to what people know and learn about how the various surfaces of that landscape will respond to different types of intervention. Choices about how to augment or minimize the way materials move in the landscape is therefore linked to knowledge of past interactions, and strategies for maintaining the desirable results of those interactions even in times of stress; i.e., storing resilience in the landscape as a form of settlement infrastructure. To think this way, however, we must have some working understanding of resilience and infrastructure as analytical terms across multiple scales of study.

1.5 Resilience in the Early Bronze Age

Resilience thinking – which I use rather than "resilience theory," to emphasize the mode of approach rather than a fixed set of principles – derives from a body of theory that originated in ecology, and has been taken up predominantly by historical ecologists thinking about society-

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[8] I originally intended to analyze a greater number of stones for use-wear traces; however, logistical problems with accessing a microscope in Lebanon did not get resolved until near the end of the study period. This therefore should serve as a case study for future work.

environment relations over time. Resilience thinking attempts to understand how and why change occurs in complex adaptive systems, whether they be ecological, social, or linked social-ecological systems, through tracing the interactions within and between those systems over time (Gunderson and Holling 2002; Holling 1973; Miller et al. 2010). Resilience thinking is about positionality; importantly, it differs from relational theories that posit all actors as exerting equivalent influence on each other, it considers the impact of "keystone species" like humans relative to their positions within a network. Therefore, these species are not central to the system as a whole, but they have certain kinds of power to exert more force on other actors in the system, while still absorbing different degrees of impact from the actors in exchange.

Whether or not a set of relationships within a given system remains stable over time is less the point of resilience thinking than whether those relationships are able to break down and reconstitute themselves over time without serious damage; temporal perspective, is therefore, a key element to the analysis of resilience. As such, much of resilience thinking accords fairly comfortably with current anthropological theory in its turn towards posthumanism; Deleuze and Guattari's rhizome (which much of posthumanist theory draws on to varying degrees) is, at its core, derived from ecological models (which they call "geophilosophy"; Deleuze and Guattari 1994, 85; Chisholm 2008). Importantly for this study, it also accords more or less with Bronze Age Canaanite texts, which emphasize the cyclicality of the land, seasons, rulership, and god's lives (often in a series of seven-year cycles). This ideology of landscape rests on the knowledge that human-environmental (and society-deity) relationships are built up and break down, and are reconstituted over time, as this is the cyclicality of life that even the gods cannot escape:

For seven years let Baal fail,
eight, the Rider on the Clouds:

no dew, no showers,
no surging of the two seas,
no benefit of Baal's voice.

Aqhat, Tablet 3, Column 1 (Coogan and Smith 2012: 47).

Archaeologists of complexity have, given the depth and closeness of their disciplinary relationship with evolutionary ecology and biological systems theories, applied resilience thinking as an approach before, focusing mainly on the durability and collapse of societies (Butzer and Endfield 2012; Hegmon et al. 2008; Redman et al. 2009), and on foraging and agricultural systems (Peeples et al. 2006; Rosen and Rivera-Collazo 2012). Part of this comes from a predisposition in some earlier archaeological research to question the resilience of subsistence economies (how on earth did they manage to make it so long?) while questioning rather the dissolution of complex societies (but why didn't they make it?). On the one hand, we have a return to the romanticizing of simple societies and their positive environmental practices in popular media (for instance, the recent New Yorker article: Lanchester 2017), and on the other, an anxiety about the possibility of collapse of complex societies (Faulseit 2015, Schwartz and Nichols 2010). This is not just residual disciplinary bias, of course, but its newest manifestation within the contemporary angst about the direction of modern societies' rapid urbanization and technologizing in the face of climate change and environmental degradation.

Resilience thinking, however, emphasizes neither stability nor change, but, rather, the fluidity between various states (Redman 2005: 72). Understanding smaller-scale processes, and how they are practically nested within larger, transforming systems, is critical to this process (Gunderson and Holling 2007, Faulseit). Rather than focusing our questions about resilience and risk on the moments of crisis, I suggest we readdress them to the way environmental practices changed while preserving possibility for return over time. What values in relation to the environment can be understood based on a society's interaction with that environment, in the sense of what was important to maintain – particularly through calculated storage practices – and what was available for modification? What does that in turn tell us about their short and long-term concepts of what was at risk in moments of political and environmental change, and whether that risk should and could be mitigated?

1.6 Environmental Infrastructures and their Demands

I suggest above that we can also begin to think of the EBA modifications of plant and stone resources as part of settlement infrastructure itself, in the sense that it is part of a storage system designed to keep materials moving under various and unpredictable circumstances. This draws us away from the temptation to think of plants only in terms of economic production – an important aspect, certainly, but one that has tended to monopolize archaeological research at the expense of thinking about other effects of plant use and landscape manipulation. Thinking about modified landscapes and their associated on-site structures as part of a system of storage, which is part of settlement infrastructure, allows us to consider as well the accretion of new surfaces and new practical and temporal demands for maintenance that such projects necessitated. Importantly, microbotanical analysis allows us to simultaneously focus our attention on plants other than the cereal staple crops usually emphasized in narratives of agrarian complex societies, and to analyze other kinds of technologies that are typically invisible except under extremely good preservation conditions, such as the precise technologies of storage constructions at TFK and Sidon. Micro-trace analyses present the opportunity to link small scale, invisible effects of everyday practices to larger scale questions of economics, yes, but also socio-political strategies and choices.

My reading of surface accretion as critical to studying infrastructure in complex societies, and as the link between the micro and the macro in this dissertation, draws from Nikhil Anand and Paul Collier, whose writings on the topic resonate with the early 20th century Lebanese poetry and, indeed, some Ugaritic poetry. Anand emphasizes the instability of surfaces, which in infrastructure "are brought into being out of a multiplicity of historical forms and techno-political relations that, while bound together, seldom fully cohere. […] these are not smooth surfaces that perform as planned; instead they are flaky, falling-apart forms that constantly call out for projects of management, maintenance, and repair." (Anand 2015). They therefore bring the past and present continuously into points of material encounter with human populations in a way that invites further manipulation, modification, repair, or in some cases, creates new opportunities out of the cracks and collapse of old ones. Storage, to recall our early definition of it, is a technology and a set of practices that additionally provides for multiple possible imagined futures.

Lebanese diasporic writing of the 20th century speaks to the idea of instability in the landscape and in the material degradation of the built environment as reshaping the Lebanese sense of identity and reflecting its already unstable condition. Palestinian-Lebanese poet Naomi Shihab Nye (1995), for instance, writes with careful attention to the small surface alterations that shape her daily post-war environment:

I break this toast for the ghost of bread in Lebanon.

The split stone, the toppled doorway.

Someone's kettle has been crushed.
Someone's sister has a gash above her right eye.

And now our tea has trouble being sweet.
A strawberry softens, turns musty,
overnight each apple grows a bruise (104).

The surfaces again grow both outward, in the apple bruising, and inward, in the kettle caving. Later in the poem, people ("each household") are brought together in the act of repair, of safety, of "togetherness" required by these conditions. In Anand's (2015) study of water infrastructures in India he also describes this coming together in moments of re-appropriation after loss: water's "bulkiness and weight" acts and reacts with metals, bacteria, and other micro-organisms to produce disruptions in its flow, and in order to compensate for exclusions from the planned sources of pressure and renewal, people often end up repurposing pipes and hardware for unexpected purposes that meet their needs.

I will suggest that the accretion of micro-traces on plant, soil, and stone surfaces were produced by a society with this sense of surface instability, and technologies were directed to maximize options as the confluences of surfaces changed, rather than to incorporate all available surfaces into a single system, in this case of staple crop production. In this sense, I attempt to describe something similar to Abdou Maliq-Simone (2012), who notes, "Always ambiguous, material connections emergent in infrastructural labor can be seized upon as a potentiality not to connect, but to express refusals to be incorporated."

1.7 A Note on the Use of Texts

It may be that resilience in times of stress, in the case of the Early Bronze Age settlements of coastal Lebanon, required strategic techniques for building up storage practices during times of plenty. To draw this out, the reader will have noticed that I have suggested that we must take into account not only the work of our anthropological ancestors, as described above, but also the ways in which the ancient and modern peoples of the coastal northern Levant talked about their relationships to the land. This requires a note of caution. Unfortunately, there is so far no evidence of texts from the Early Bronze Age Levant itself. Nonetheless, I suggest that we extend our interpretive reach and take into account the closest written evidence we have: the Late Bronze Age texts from Ugarit, and the Early Bronze Age IV archives from Ebla, alongside oral histories and place-based story-telling still prevalent in Lebanon today. I emphasize my understanding and advocate to others that these texts should not be used as direct analogies for the thinking of the Early Bronze Age occupants of the Lebanese littoral – indeed, the socio-political and technological landscapes of the Middle and Late Bronze Ages, let alone modern Lebanon, were quite different than those of the EBA, and we can certainly imagine at least some differences in religion and religious practice, as well. However, I agree with most philological scholars of these texts, including Michael D. Coogan and Mark Smith, who remind us that the scribes in some cases note that they are copying other tales, and it is probable that many of the stories from Ugarit were composed "centuries before they were finally written down" (Coogan and Smith 2012: 4), and retain traces of older beliefs and practices (Schaeffer 1939; Wyatt 1998). The Eblaite texts were written with Sumerian characters, but in a local language classified as Northwest Semitic, closest to Ugaritic, Phoenician, and Hebrew (Pettinato 1975, 1979; Fronzaroli 1977), suggesting a closer linguistic link to those regions that remained without textual expression. Similarly, the gods mentioned at Ebla, the material culture, and the references to greater Canaan provide a picture of a society in the process of syncretizing various influences, but still very much socio-culturally linked to Greater Canaan (Vigano and Pardee 1984; Matthiae 1979, 1995, 2008; Vidal 2006). Indeed, the texts specifically describe the Lebanon as already a conceptually discrete geo-cultural entity – a general place where important port cities were located (Vigano and Pardee 1984: 13; Pettinato 1980: 136).

As I am not a philologist myself, and I do not aspire for this document to attempt any such textual analysis, the stories are used here to guide our thinking towards ways of understanding landscape that emerged in the place and closer to the time of study. If we can accept the meaningfulness of modern anthropological theory of landscape, certainly we must be able to incorporate ancient Levantine stories about the land into our interpretive imaginations as well. I will use these stories alongside the traceological accretions of plant and stone evidence to show the ways in which practices on the land stored and reinforced the memories, techniques, and possibilities that were ultimately important – perhaps critical – to maintaining a just, resilient, and balanced society.

1.8 Organization of the Dissertation

As briefly described in the beginning of the text, this dissertation is divided into six chapters to present the data.

Chapter Two delves into the history of research that informs this dissertation. This includes a closer look at the history of archaeological study of the Early Bronze Age in the coastal Levant with a focus on Lebanon, archaeobotanical and paleoclimate research of this time and region, ground stone studies, multi-regional archaeological studies of storage, and integrated landscape approaches to EB Levantine place. This chapter also introduces in detail the specific methods involved in obtaining the microbotanical and lithic micro-wear data, as well as how that data is organized and analyzed.

Chapter Three presents descriptions of the data sets in more detail, including full lists of the sediment samples processed for phytolith analysis and a summary of their assemblages, and a description of each ground stone artifact analyzed.

Chapter Four examines the on-site storage compartments at TFK and Sidon through the phytolith data, using a technological and infrastructural analytical lens. Here we see how the more traditional material traces of storage are represented at each site, and how their construction technologies and contents both indicate long and short term planning, and reveal the complex relationships to multiple eco-zones necessary to sustain their usefulness for such planning. It also looks at some new evidence that bolsters our understanding of possible interconnectivity between sites and regions at the time.

Chapter Five takes a closer look at the way in which the micro-traces of use wear on the stone grinding tools inform the valuation and curation of geological zones. It particularly examines the way different stone materials are curated over time, based on indications of breakage and reuse. This indicates there was intentional planning for different processing options through the types of use and reuse, not just in terms of processing technique, but in terms of mobility and access, as well. It then relates the planning of tool-curation to that seen in the landscape use of the previous chapters to suggest that overlapping these analytical approaches gives a more nuanced view to ancient approaches to storage, possibility, and landscape.

Chapter Six draws the threads together to suggest that combined, this study can be integrated with Bronze Age Levantine concepts of just and justified rulership as read in the ancient texts, and tell us about the way in which daily landscape practices were integrated in the developmental trajectories of EBA Levantine complex societies. Rather than conclusions, it presents a series of suggested paths forward that are newly introduced by interweaving the data from this project. Finally, it proposes that thinking of resilience and landscape storage in the terms presented in this study has promise for confronting our own society's present engagement with over-expansion and climate change.

Chapter Two

Background, Methods, and Histories

2.1 Apricots and Objectives

There is a popular saying in Arabic, expressed throughout the modern Middle East, that goes "bukra fil mishmish" (بكره في المشمش) or "tomorrow, in [the time of] the apricots." It is an idiom used to express something along the lines of "wishful thinking," or to suggest that something desired likely won't happen. The reasoning is that, on one hand, the apricot season is so beautiful but so short, it's practically imaginary (it never really arrives). Along similar lines, because apricots need to be eaten quickly before their texture turns mealy and unappetizing, and because they aren't easily stored, it's unlikely that tomorrow will be a good apricot day. This phrase expresses all at once ideas about expectation, desire, humor, time, and memory through the evocation of the transient sensuousness of the fruit, as it grows, is eaten, and decays. It invokes the way in which anticipation and the passage of time are both also senses integral to a life tied to the land. It holds within it the sense that the processes of living and dying are present simultaneously, and are expressed through the interactions between plant products of the earth, the seasons, and the human body.

It is an attentiveness to such intimate kinds of knowledge that emerge between people, plants, land and stones through multi-generational practices in a specific place that I am interested in, at the base of this project. This is an ambitious goal, and one that certainly cannot be completed within the constraints of a PhD project. However, I hope that setting that goal will at least move this research a little closer towards more nuanced ways of thinking about how such relationships emerged and then, importantly, were preserved – stored in the land and the infrastructure of the earliest complex, aggregated EBA settlements in coastal Lebanon, as new technologies and a volatile climate were buffeting that small stretch of stony Mediterranean shoreline. Like the time of the apricots, the goal must be pursued, even if it can never be fully reached. To that end, I bring together new techniques that make visible the smallest traces of human-plant, human-stone, and plant-stone contact over the course of the EBA occupation at TFK and Sidon, introduced in Chapter One. This chapter presents a history of the research that has come before me and laid the groundwork for this study, as well as an outline of the methods I use to produce the data sets and come to the conclusions that are presented in the remaining chapters.

2.2 Paleobotanical and Climate Studies in the Near East

Human interactions with the environment, and especially the reciprocal impact that humans and climate have had in the past and are continuing to have today, has become a critical and increasingly popular topic for research in the past decade. As the vulnerability of our own societies to climate change becomes more obvious, society at large is only beginning to take seriously the fact that that change has been exacerbated and accelerated by past and current human activity. Environmental scientists, on the other hand, have long understood this to be true, and have been intensifying their efforts to explore and express the variable ways in which human activity has impacted environmental systems and climate patterns in the past. Environmental archaeologists, working often in collaboration with climatologists, geologists, and environmental scientists, are increasingly making these questions a critical part of their research programs.

All this is to say, there are plentiful studies available today that present a far more comprehensive examination of the Southwest Asian climate data than I have space for in this dissertation. I will review the evidence quite briefly, therefore, as it pertains to this specific study, and I will leave the interested reader to find further information in the wealth of new documentation emerging on the topic (Goodfriend 1999; Litt et al 2002; Fagan 2004; Flannery 2005; Rosen 2007; Casana 2008; Weninger et al 2009; Roberts et al 2011; Rosen and Collazo-Rivera 2012, for instance).

Broadly speaking, this dissertation follows Rosen's dates for the Holocene, generated from multi-proxy data sources, as a geological epoch in relation to human societies of the Levant (2007: 70). This chronology sub-divides the Holocene into three broad sub-phases, the Early (c. 9500-5500 cal. BP), Middle (5500-2000 cal. BP), and Late (2000 cal. BP). These are intended as general categories that encompass the major climate fluctuations in relation to human behavior over the course of this epoch.[9] By this metric, the EBA settlements of coastal Lebanon fall comfortably into the range of the Middle Holocene.

Local proxies for Holocene climate patterns in the central and northern Levant remain few and far between, although a few significant exceptions in the form of pollen cores and one speleothem are discussed below. In the Southern Levant, Cyprus, and Anatolia, however, research has been much more extensive, and we can extrapolate to a certain extent from these studies. It is widely accepted that the Middle Holocene was a period of significant climatic and environmental change throughout Southwest Asia, with punctuated episodes of "Rapid Climate Change" (RCCs, typically referring to rapid aridification processes) that interrupted alternating wet/dry phases throughout the period (Mayewski et al 2004; Clarke et al 2012; Rosen 2007). Rosen reminds us, however, that what seems "significant" on a histogram showing proxy patterns is different than what was significant to the people living in that environment – even

[9] It is unfortunately beyond the scope of this dissertation to delve into the arguments surrounding the "Anthropocene" as a geological epoch defined by human impact on the atmospheric and geochemistry of the planet (Crutzen 2000).

small changes were felt greatly by small-scale subsistence farmers, whereas long periods of drought were manageable by wealthy estates sitting on aquifers, for instance (Rosen 2007: 70). Climate patterns must always be observed in terms of patterns of human behavior, the opportunities available to them to adjust to changes in those patterns, and – perhaps most critically – their willingness to do so (Rosen 1995; Rosen and Rosen 2001).

The fourth millennium BCE[10] saw the emergence of the complex, densely aggregated settlements and their attendant technologies that characterize the Early Bronze Age in the coastal Levant. It also coincided with a restructuring of global climate patterns, largely in terms of transitions to more arid conditions throughout the northern hemisphere sub-tropics and adjacent eco-zones, including Lebanon and the Eastern Mediterranean/Levant generally (Damnati 2000; Guo et al 2000; Brooks 2006; Thompson et al 2006; Clarke et al 2012). A number of multi-proxy lines of evidence point to a general aridification period globally during the late fourth millennium BCE that coincides with most areas that remain arid to semi-arid today (Brooks 2010). This aridification period opens the "long fourth millennium BCE" in the region, which stretches until a second aridification episode identified as spanning several hundred years at the end of the third millennium BCE. This long fourth millennium, then, is bracketed by these so-called "8.2 and 4.2 kya drought events," rapid aridification episodes that affected a large part of the planet, and specifically Western Asia, although their impact on different human societies is still hotly debated (Cullen et al 2000; Weiss 2012).

[10] Climate dates are typically referred to in cal. BP. However, as I am using BCE dates for the rest of the dissertation, and speaking about climate in relation to the archaeological material, I prefer to avoid confusion by converting to BCE dates for this section as well. When reading climate-focused literature, however, the 6th millennium cal. BP is the equivalent time frame to the fourth millennium BCE here.

The primary lines of evidence used to generate proxy data for climate variation in Southwest Asia are isotopes from (mainly) speleothems, pollen and foraminifera from terrestrial and marine cores, and geomorphological studies of lakes, alluvial sections, sediment cores, and dust particle analyses (Rosen 2007; Brooks 2012; Clarke et al 2012). Because each of these lines of evidence has its own limitations and margins of error, particularly in terms of dating, they must be combined to give a completer and more reliable picture of climate patterns throughout a given region. It can be even more difficult to link these proxies up with precise patterns of human behavior, as the chronological resolution on speleothem results, for instance, can have a range of several hundred years (see, for instance, various discussions of the dating of the Soreq Cave speleothem from Israel: Bar-Matthews et al. 1998, 1999, 2000; Bar-Matthews and Ayalon 2004).

Both the Soreq Cave isotopes and a series of speleothems from the Judean Hills (Ford and Schwartz 1999) indicate a rise in δ^{18} levels at the beginning and end of the fourth millennium BCE (indicating aridification), with a drop of those levels in the middle (indicating increasing moisture), which would support the generalized climate pattern of aridification episodes bracketing a generally wetter, warmer Middle Holocene, as described above. The Jeita Cave speleothem, in central coastal Lebanon, however, has been interpreted as evidence for a very different picture in the Northern Levant. While the original researchers report an early fourth millennium aridification tendency, they identify a Middle Holocene return to wet conditions for only a century before aridification resumed (Verheyden et al 2008). Later researchers reexamined the core and went even further to propose a model in which five-hundred year wet/dry episodes that were distinctly and persistently at odds with the wet/dry processes of the Southern Levant (Cheng et al 2015). They suggest that in some cases, enhanced warm southerly-southwesterly air flow that decreases precipitation in the Southern Levant may in fact drive precipitation up in the Northern Levant, accounting for discrepancies in the way these regions experienced regional climatic variability (Ibid: 8647-8648).

The pollen records for the region complicate this picture further, both giving more localized data but raising their own problems in terms of pollen's high susceptibility to long-distance travel and contamination. Pollen has the same limitations of all archaeobotanical data, as well, in that certain plants have higher and lower rates of pollen production, resulting in over or underrepresented taxa in the ancient record. While there have been no pollen cores taken from the coastal plain of Lebanon itself, it may be possible to make some inferences by looking at the palynological data from immediately surrounding areas. The closest available cores come from the harbor area of Sidon (Morhange et al 2000), the Biq'a Valley (Hajar et al 2008, 2010; Cheddadi and Khater 2016), the Hula Valley (van Zeist et al 2009), and the Ghab Valley (Bottema 1975, Yasuda et al 2000).

The Sidon marine core provides the only pollen data currently available from the Lebanese littoral itself (**Figure 2.1**). However, it was taken just off the coast line, as part of a project investigating the development of early ports around Sidon. As such, the published results concentrate more closely on sedimentology and lithology than on the pollen record. In addition, very few dates were taken, and nothing older than 5000 cal BP could be identified, as much of the area representing earlier time periods was contaminated. Across the third millennium BCE, however, which is our primary time range of interest, a general increase in olive and gradual decrease in grape can be seen, along with a generally decreasing trend in arboreal pollen overall; this can likely be related to increasing cultivation in the vicinity of the growing settlement during this time (Hajar et al 2010). There seems to be a small spike in maquis pollen (such as

Chenopodiaceae) towards the end of third millennium, which may indicate the environmental response of an already heavily modified landscape to increased warmer and dryer conditions.

The first two Biq'a Valley cores were taken from the interior slopes of the southern Biq'a Valley – one from the eastern face of the Lebanon Mountains, in Aamiq, and one 12 km away on the western face of the Anti-Lebanon Mountains, at Anjar/Chamsine. Neither core suggests a particularly notable impact from rapid climate change events, either at the beginning or end of the fourth millennium BCE; the authors argue that human activity had a much more active effect on shaping the environment during this time than the reverse (Hajar et al 2010, 751). They establish this by direct comparison of specific "anthropogenic indicators," as based on the model developed by earlier studies for the Eastern Mediterranean (Bottema and Woldring 1990; see Fig. 6). They then calculate correlations between Cichorioideae (which they argue is a variable independent from climate variability and closely related to soil perturbations) and taxa that they propose to be more susceptible to global climate changes (such as Chenopodiaceae*, Ephedra,* and Ericaceae for local pollen, and *q. cerris* for exotic pollen) (**Figure 2.2**). They argue that the anti-correlation between the axes for the Aamiq core indicates that the second axis is dependent on the first. This would imply that changes are related more to anthropogenic soil perturbations, including already extensive deforestation, at Aamiq, whereas the more direct correlation of the axes for the Chamsine core suggests that this area was left to the whims and effects of regional climate variation to a greater degree (Hajar et al 2010, 753).

Cheddadi and Khater (2016) reexamined these cores and added an additional third core from the northern Biq'a Valley marsh, Al Jourd. For this study, they adjusted the age-depth models available for Ammiq and Chamsine records (Hajar et al., 2008, 2010) as well as the new Al Jourd core according to the marine chronostratigraphy proposed by Rossignol-Strick (1995).

With the new dates in place, the Ammiq and Chamsine records show somewhat different patterns; there is in fact an increase in arboreal pollens in the former, a fairly consistently high arboreal count in the latter, and a gradual increase in the new Al Jourd core. This would disrupt a narrative of extensive deforestation by the fourth millennium BCE. The anti-correlation between grasses and invasive weedy and herbaceous taxa (like Asteroidea) is still seen in the Aamiq core, supporting Hajar et al's interpretation of anthropogenic influence in that area; however, the fairly consistent levels elsewhere show no effects of climate or anthropogenic influence at either Chamsine or Al Jourd. Moreover, oak and cedar occur at internally consistent levels at each site, but those levels vary dramatically between the sites; similarly, climate indicator "envelopes" of taxa that can act as proxies for precipitation levels vary between each core. This indicates locally diverse micro-climates as well as locally variable programs of land use and eco-zone preservation (Cheddadi and Khater 2016: 150). These patterns, at least, seem independent of the aridification episodes seen elsewhere, and lend further evidence to the increasingly supported idea that the effects of climate change were socio-technological and locally variable, rather than externally driven (**Figure 2.3**) (Rosen 1995, 1997; Riehl et al 2008; Riehl 2015; Ur 2015).

The Hula and Ghab Valley cores are less extensively discussed here, as they are farther from the sites in question and have extensive literatures, as the Hula core in particular has dating concerns associated with reservoir effect (Van Zeist et al 2009; Bottema 1975; Yasuda et al 2000). Generally, however, they indicate expansion of oak and pistachio forest from the mid fifth millennium BCE, persisting throughout the Middle Holocene (not unlike the Al Jourd and Chamsine cores show for cedar and oak). Deforestation does not appear to be extensively undertaken until after the EBA, and the authors suggest little anthropogenic disruption beyond the immediate vicinity of aggregated settlements. Notably, however, there is a much more dramatic peak for *Olea* in the mid-third millennium BCE levels of these pollen cores, followed by a sharp decline, indicating that expansion of staple crop agriculture to a point that was unsustainable in the face of aridification and/or political pressures. This is not seen in the Lebanese cores, and is further discussed in the following chapters.

Geomorphological evidence from the Southern Levant demonstrates that alluviation increased during this time, likely caused by a combination of greater rainfall and anthropogenic encouragement. This caused overflow from the rivers onto the banks, creating floodwater regimes that were ideal for agriculture in a wet/dry seasonal setting such as the Middle Holocene provided. However, with increasing aridification towards the end of the third millennium BCE, these streams began incising their beds and decreased the availability of floodwater for farming (Rosen 1995, 2007; Goldberg 1994). However, this pattern cannot necessarily be extrapolated as evidence for climatically-induced landscape and economic changes in Lebanon, as the geomorphology is dramatically different. Alluvial pathways and terraces along the Lebanese littoral are found along the foothills descending from the mountains, above a karstic base geology that acted as a system of natural reservoirs (Pustovoytov 2011; Nader et al 2014). This comprises a very different geomorphological situation, whose current hydrology is still poorly understood, let alone its past conditions (Edgell 1997; Shaban 2008; Mohammad 2015). This provides promising ground for future geoarchaeological investigations.

Given the variability of these different climate proxies and disputes over their relative significance, I will be relying most heavily on combined and normalized proxy models for comparison to the phytolith and ground stone use patterns from Sidon and TFK. Joanne Clarke et al. (2012) collected all known speleothem and lake core records for the Southern, Central, and Northern Levant (pollen records were excluded due to the high probability of anthropogenic influence, as discussed above). They incorporate reliable marine records for foraminiferal, isotopic, and mineralogical content. Records of different types from the same locations/cores were used to adjust for errors in single samples (see Clarke et al 2012: 99-100 for full description of quantification methods). This produced a model for regional rainfall by century for Anatolia, the Southern Levant/Cyprus, and Mesopotamia (**Figure 2.4)**. The former three regions are compared to the original results in this dissertation to gain a sense of regional comparability, as the Mediterranean coastal geomorphologies and ecological heterogeneity of those areas are more similar to those of Lebanon than is Mesopotamia. Interestingly, for the Southern Levant/Cyprus, there appears to be a generalized pattern of extreme dry – increasing wet conditions – extreme dry for the third millennium BCE, as indicated by the other proxies described above. However, the pattern is exactly reversed in the Anatolian data. This underscores the point made by the researchers of the Jeita speleothem, which indicates that similar climate-influencing factors can cause very different extremes in different geographical and geomorphological zones.

Lebanon (like many mountainous coastal landscapes) is made up of diverse microclimates which support one of the highest densities of floral diversity in the Mediterranean basin - itself renowned for being one of the most biologically diverse regions of the world (Jaafar et al 2017; Beydoun and Estephan 2005). It will therefore be necessary to develop much more robust multi-proxy studies for a range of locally diverse eco-zones in Lebanon itself in order to understand the past expressions of those micro-climates and how people interacted with them.

2.3 History of Levantine Archaeological Research and Its Narratives

Levantine archaeology, like all regional archaeologies in their own ways, has been driven over time by narratives that are more often related to the time periods, methods, or historical traditions of the archaeologists producing them than the people being studied (Wengrow 2016a; Levy and Jones 2018). For the Bronze Age Levant, these narratives have frequently circulated around the idea of "civilization," as an identifiable object and event that could be materially recognized, tested for, and explained. Of course, the underlying assumption was that the emergence of "civilization" in the Bronze Age Middle East was at its core also the emergence of European civilization. At the height of nineteenth and early twentieth-century archaeology, the ability to scientifically verify this was critical to the colonial projects of various European regimes, and therefore was a political project as much as an intellectual one; as James Henry Breasted – the founder of the University of Chicago Oriental Institute – famously wrote, "Civilization arose in the Orient, and Europe obtained it there" (Breasted 1916: v).

From these origins, narratives for the Bronze Age emergence of Levantine social complexity[11] begin with some version of the assertion that "urbanism, and the route taken by different societies towards it, is the primary story of the Early Bronze Age Levant …" (Greenberg 2014: 269; cf. Chesson 2003; Chesson and Philip 2003; Richard 2014). In this sense, the Early Bronze Age came to be considered "a kind of rehearsal before the golden age of Canaanite civilization in the Middle Bronze Age" (de Miroschedji 2014: 322). The alternations between aggregation and dispersal of aggregated settlements during the EBA, and especially marked during the so-called "Intermediate Bronze Age" (here referred to as the EBIV, or Early Bronze IV), are considered to be "discontinuities," with the final EBIV discontinuity marking a pronounced "failure" of early complexity and "abandonments" of EBA "failed" towns

[11] I would like to reiterate here that while "urbanism" clearly is the dominant term used to describe the aggregating and nucleating processes of settlements during the EBA Levant, I will not be engaging with that literature or terminology here, as it is beyond the scope of this project to establish the case for or against "urban" as an appropriate identifier. However, there will occasionally be important quotes in the literature that use this term, and it cannot be avoided. These should not be taken as assertions of this dissertation, but rather considered within the context of the larger discussion of settlement aggregation and dispersal in relation to local environments.

(Dever 1995; Palumbo 1990; Esse 1991; Joffe 1991). Weiss described the EBIV as a "collapse" that represents "an alluring Holocene example of societal responses to abrupt climate change across the eastern Mediterranean and west Asian landscapes" (Weiss 2014: 367; see Fall et al 2018 for discussion).

These underlying narratives have long driven an approach to the archaeology of the EBA Levant that has obscured the nuances and successes of local variability in several important ways. First, until the last few decades, there has been a focus on Mesopotamia and Egypt as external drivers of social change in the Levant: Stager's famous "Port Power" model is a classic example that has influenced much subsequent work (1985). This model (simplified here) proposes that Egypt lacked critical agricultural resources like olive oil, wine, and timber, and the Levant lacked centralized administration of their plentiful resources. This allowed the Egyptians to dominate ports and networks of trade, which in turn led to broader political domination; it was the Egyptian presence in the Levant in the early part of the EBA that provided the model for complexity (urbanization) that would subsequently be attempted by local elites after the Egyptians left.

Thus, as Fall et al. (2018: 92-93) describe, "the prevailing interpretive narrative for Levantine civilization stitches together archaeological patterns of settlement nucleation and disintegration, junctures of climatic stress, and historically documented social and political disruptions." By holding urbanism (as represented by large-scale Egyptian and Mesopotamian models) as the gold standard and goal for emerging Levantine complex society, and indeed, for "civilization," this narrative holds within it the always-present anticipation of disjuncture and collapse, then, for EBA settlements; all explanations must somehow account for ultimate failure. The data presented in this project complicates that narrative by demonstrating that cyclical behaviors previously seen as "discontinuities" may be better understood as continuous patterns built into the infrastructure of small-scale societies engaging with diverse local environments and predictably unpredictable climate patterns. While this study, and the research it influenced, has certainly helped to broaden our understanding of inter-regional relationships and the ways in which they can be theorized for the EBA Levant, it helped to sustain a view of EBA Levantine socio-political development as essentially derivative, linear, and doomed (Greenberg 2003; Wengrow 2016a; Chesson and Philips 2003). For some, Mesopotamia and the "Uruk Expansion" was the analogue for Egypt in the Northern Levant, considering trade relationships with inland Mesopotamian settlements and colonies as driving developments trending westward (Adams 1966; Redford 1997; Algaze 1993).

Within Lebanon, Leon Marfoe (introduced in Chapter One) was the first to really embrace – analytically and conceptually – the fragmentary Lebanese geography and its diverse micro-climates and micro-environments as a critical part of understanding the development of social and political complexity. He coined the "pastoral-urban continuum" to describe the cyclical expansion and contraction of Lebanese small-scale complex EBA settlements (Marfoe 1978, 1995, and 1998). In Marfoe's analysis, the relatively favorable, but still unpredictable and unstable, environments of Lebanon afforded local societies the opportunity to alternate their subsistence strategies without dissolving the kinship and social bonds, and small-scale political organizational ties that held society together. Centralization (nucleated aggregation) could be enforced periodically (Greenberg 2002), but he saw a natural disinclination towards centralized authority based on the centrifugal tendencies of small-scale societies, the resilience afforded by built-in flexibility in subsistence strategies, and established social relationships to the fragmented environment.

Marfoe’s work has been hugely influential to my own research as presented here, and in many ways the data presented in the following chapters supports his survey-based models. He also influenced a generation of researchers more interested in local variability than in monolithic explanatory models (de Miroschedji 1989; Joffe 1993; Greenberg 2002; Badreshany 2013; Genz et al in press). Nonetheless, sustained urbanism (or nucleated aggregation) remains a major point of achievement and a benchmark for success in many studies, with an emphasis on trade relations, and identifying the institutions that might have directed them (Dever 1987; Finkelstein 1993; Ilan 1995; Milevski 2011, for a Marxist but still economic/institutions-driven approach). This persists despite the lack of evidence thus far for extensive interregional trade in agricultural products between the Levant and Egypt or Mesopotamia until the Middle Bronze Age (Genz 2003).

Landscape approaches that incorporate local ecologies are beginning to increase in Lebanon and the broader Levant, however, (Harrison 2003; Wilkinson 2003; Lawrence et al 2017). The recent appearance of increasing numbers of better radiochronologies in the region has helped to reorient perspectives on cause and effect, collapse and growth, and local variability in the region (e.g., Bourke et al. 2009; Golani and Segal 2002; Regev et al. 2012; Höflmayer et al 2014, 2016). It is beginning to appear that the Early Bronze Age and each sub-phases began earlier than previously thought, and perhaps not contemporaneously throughout the region. This dissertation builds upon recent research that recognizes the diversity of trajectories taken by different early complex societies throughout Southwest Asia. Mesopotamia and Egypt, which were each, by the end of the 4th millennium BC, host to densely urbanized, complex systems of societies, are no longer assumed to be the only models by which complexity in the region can be measured (Fall et al 2018; Greenberg 2002; Chesson and Philip 2002; Genz 2012), and "collapse" is now a popular topic to deconstruct (McAnany and Yoffee 2010; Faulseit 2015; Middleton 2017, to name a few). The research presented in this dissertation is engaged with the literatures emerging in this new research trajectory – one that seeks to understand local diversity as constituent parts of, rather than exceptions to, grand narratives of Levantine complexity in relation to the environment.

2.4 Resilience and Storage in the Literature of Ancient Canaan

Resilience is defined by the International Panel on Climate Change (IPCC, 2014, 1772) as "The capacity of a social-ecological system to cope with a hazardous event or disturbance, responding or reorganizing in ways that maintain its essential function, identity, and structure, while also maintaining the capacity for adaptation, learning, and transformation." In early ecological theory, resilience was used to refer to the ways in which ecosystems maintained equilibrium and stability. Holling defined resilience in a seminal paper as that quality which "determines the persistence of relationships within a system and is a measure of the ability of these systems to absorb change-of-state variables, driving variables […] and still persist" (Holling 1973: 2). Perrings later expanded this definition, writing that "in its broadest sense, resilience is a measure of the ability of a system to withstand stresses and shocks—its ability to persist in an uncertain world" (Perrings 1998: 221).

What I propose throughout this dissertation is that resilience in the EBA settlements of coastal Lebanon was not a quality waiting to be activated by crisis or acute stress, but that it was a way of living in relation to the environment that was built into the fabric of society. In this sense, adjustments to and reorganizations of ways of living were part of daily life and generational knowledge, rather than worst-case-scenario responses. The landscape and the settlement infrastructure served as zones of "storage" for possibility (of changing subsistence strategies and settlement organization), memory (of past land use practices and relationships), and balance (in relationship to a changing land and climate), as well as the storage of actual material goods (plants and stones are studied here, but of course I imagine other kinds of material culture could be included as well). Continuity in behavior then shouldn't necessarily be seen as the absence of stressors on society, but rather as an infrastructural resilience that allowed stressors to be weathered without dramatic change.

The modes of storage I propose comprise ways of preserving alternative possibilities in the landscape, and ways of building multiple eco-zones into the storage facilities within the settlements so that they remained intertwined materially, economically, and conceptually. This argument is developed out of an intellectual history whose narratives are based in storage, as much as in resilience. The links between storage, surplus agricultural production, and the development and robusticity of social complexity were explored by Gordon Childe over half a century ago, and they continue to hold a significant place in intellectual narratives today (Childe 1950; Balbo 2015; Forbes 2016). Processualism and its attendant neo-evolutionary concepts in the archaeology of the 1960s further emphasized the connection between plant products (primarily foodstuffs) and a variety of ways of storing them socially, materially, and ideologically (Binford 1965, 1984; Speth 1990; Kelly 1992; Earle 1997). Storage is clearly not just a Southwest Asian phenomenon, but forms a crucial part of economies all over the world, and manifests in a wide variety ways, intended for many kinds of containment of different cultivators (examples of global studies outside of Southwest Asia: Abass et al. 2014 Abass, et al. 2014; Baoua et al. 2015 Baoua, et al. 2015. Bayliss-Smith, T., and E. Hviding. 2015, Covey et al 2015). Storage has been studied for hunter-gathere/foraging societies as well as complex societies (e.g. Price 1962 Price, J. A. 1962; Testart 1982 Testart, A. 198; Soffer 1989 Soffer, O. 1989: 719–732).

Although storage facilities have been examined and interpreted from the earliest days of archaeological inquiry (e.g. Evans 1935 Evans, A. J. 1935: 630–648), we are only beginning to be able to assess the range and details of most storage technologies. Some storage facilities, like the magazines at Knossos, are spectacular and seem to clearly indicate the social and political power associated with stored produce (e.g. Christakis 2004 Christakis, K. S., 2004.). Others, such as those in the Cuzco region of the Andes, the heartland of the Inka, are designed with complex systems of ventilation and drainage to create internal micro-climates appropriate to different plant products (Covey et al 2016; Salomon et al 2016). While all of these studies demonstrate that storage is linked in a material, accessible way to the relationships of people to their places, especially via their use of plant landscapes, there have been few studies yet to explicitly link those data sets and interpret them together (Rothman and Manzanilla 2016).

This dissertation brings stone and plant data sets together to think about how modes of storage were built into the settlements in question to produce a model of societal resilience that was not reactive, but always present and accessible. Resilience thinking, in the anthropological literature, emphasizes neither stability nor change, but, rather, the fluidity between various states (Redman 2005: 72). Understanding smaller-scale processes, and how they are practically nested within larger, transforming systems, is critical to this process (Gunderson and Holling 2007, Faulseit). I find that the texts of the ancient Canaanite world emphasize similar qualities in their descriptions of human-god-land relationships, and these are integrated into the interpretations of each chapter.

Due to factors that remain unknown,[12] the Early Bronze Age people of the Levant did not leave their own written records. We do have evidence of standardized intra-settlement communication in the form of weights and measures (in the case of TFK, the earliest scale beam in the region: see Genz 2011), and large collections of cylinder seals with iconographic impressions, but these of course do not communicate to us the kinds of ideas of personhood, society, or beliefs and practices that we, as anthropological archaeologists, might find convenient (or at least, we have not yet figured out how to read them). This has meant that any information about belief systems and social, political, or economic structure of these societies has had to be derived from archaeological material or inferred from the texts of neighboring and descendent communities.

In the case of coastal Lebanon, the closest analogy that we have in the literature are the texts from Late Bronze Age Ugarit, on the Syrian coast just north of the Lebanese border. It is quite certain that Ugarit and the coastal centers of Lebanon – at the very least, Arqa, Byblos, Sidon, and Tyre, possibly further south to Dor as well– shared a cultural milieu, based on a variety of factors: the similarity of material culture, the frequent mention of these settlements together in the Ugaritic religious texts and in texts written by outsiders describing the coastal Levantine system, and the shared iconographic repertoire. How far back this extends is, of course, unclear at this time and the comparison must be taken with a grain of salt, given that we are considering settlements 1500 years older than the texts in question. Nonetheless, there is strong evidence for some degree of continuity (if, certainly, there must also have been development and change) in belief systems of the Bronze Age northern Levantine coast. The

[12] Although it has been suggested that the Levantine communities, due to their trade relationship with Egypt, may have used papyrus more frequently for record-keeping than clay tablets or stone. As no strong evidence for papyrus in EBA Levantine settlements has been found, however, this remains largely speculative.

only relatively nearby texts that are actually contemporary with the Early Bronze Age settlements – the EBIV archives from Ebla – may be contemporaneous, but formed part of the Greater Mesopotamian cultural landscape to a far greater extent that the Levantine settlements did. We will attempt to consider them together (loosely, as this is not a philological study), to piece together an idea of early coastal Lebanese modes of thinking about the landscape that might help us understand the environmental archaeology data in its social context. This task of stretching our collective senses of cultural time and space is appropriate enough, as the texts in question indicate a strong tendency of these early populations to spatialize time and temporalize space in relation to the relative fertility, abundance, and usefulness of landscape, as we will see below (Coogan and Smith 2012; Ayal-Dashan 2015; Glassman 2017).

The Ugaritic and Eblaitic literature, as well as the assorted popular myths still current in local folklore, all demonstrate a common deep concern for the way appropriate behavior in relation to place and landscape (and often specific resources therein) are tied up with good rulership and the resilience of family and community. Indeed, the notion of appropriate and adaptive rulership – and respect for the limitations of that rulership – is a key component to these texts. I emphasize that these cannot be read as direct analogues for Early Bronze Age social and religious systems, and I am not attempting to do so by using them here. Instead, I hope to use these texts as invitations to consider older, non-linear non-Euro-American ways of knowing the landscape and how it fit into social paradigms, from contexts that are arguably closer to those experienced by the settlements examined here. I will then bring these considerations into conversation with both the data from the sites, and contemporary conversations surrounding resilience and resilience thinking in the academic literature.

This is what resilience thinking in ecology, anthropology, and the environmental sciences urges us to consider, as well. Human societies that take on a cyclical relationship with their environments, and that take into account the reciprocal nature of resource use and landscape development, stand better chances of persevering through the predictable unpredictability of life, specifically in the face of such threats as climate change and political interventions that effect resource availability and force modifications to subsistence strategies. This is a lesson for how we approach the past, and how we might proceed into the future.

2.5 Methods: History and Application

2.5.1 Phytoliths

Phytoliths (from the Greek words for "plant-stone") are siliceous micro-bodies formed inside plants through the uptake of soluble silica, or monosilicic acid (H4SiO4) with ground water (Piperno 2006). The silica is deposited in the plant as generally amorphous (non-crystalline) solid silicon dioxide (SiO2) in the cell walls, interiors and intercellular spaces, through passive and active silica deposition during the process of evapo-transpiration (Piperno 1988). The siliceous casts formed inside these cell and intra-cellular spaces is called "opal" or "opaline silica," as the geochemical makeup is quite similar to that mineral: phytoliths contain water (4-9%) and significant amounts of nitrogen and carbon, along with possible trace amounts of aluminum, chlorine, copper, iron, manganese, phosphorous and titanium (Prychid, et al. 2004). The degree of silicification each plant produces (or amount of silica the plant takes up) is caused by of two variables: transpiration and soil silica content (Piperno 1988). Higher transpiration rates generally produce increased silicification (i.e., more and more strongly silicified phytoliths) (Piperno 2006). The rate of transpiration depends on humidity, temperature, wind, light and soil water supply; thus why investigating phytoliths can help us understand micro-climatic factors in the past, and why understanding those factors from other proxies helps us understand phytolith assemblages better. Another variable is that plants silicify different cell types at varying levels of silica saturation: the most commonly formed phytoliths are found in the plant's epidermis, where they help the growth of the plant (Chen and Lewin 1969; Takahashi and Miyake 1977) and can act as a deterrent to herbivores (Hanley et al 2007; Coley and Barone 1996).

For the purposes of archaeological analysis, an important feature of phytoliths is their resistance to decay and to other taphonomic processes that cause problems in the dating and contextualizing of most archaeological botanical remains. Basically, phytoliths stay in the sediment where the organic plant body decayed, providing a durable and robust record of past vegetation and plant-use (Piperno 2008). There are other limitations to phytolith analysis, of course. Phytolith production is rare or non-existent in some plant families, including aroids (Araceae family), Amaranthaceae and Chenodpodiaceae (Piperno 2006; also discussed above as indicators of anthropogenic land use). Grasses, sedges and palms (monocotyledons), on the other hand, tend to produce phytoliths fairly prolifically, and their morphotypes are often distinctive to plant family, genus and more rarely, species. Most woody trees, shrubs and other herbaceous dicots produce far fewer phytoliths, with more irregular forms (Albert, et al. 2000). The redundancy of plant cellular structure and, consequently, phytolith morphology can also be a limiting factor in some forms of phytolith analysis. These redundancies mean that different plants produce the same kind of phytoliths.

On the other hand, phytoliths are uniquely useful for identifying plant parts that can be fragile and often are not otherwise preserved (stems, leaves, husks, for instance). They also allow for both general (monocot vs dicot) and specific identifications of certain taxa (grasses in particular). These characteristics of phytoliths afford the opportunity to assess specific activity areas and plant processing stages with more specificity than is otherwise typically possible. Furthermore, phytoliths provide a picture of past vegetation zones and plant-use practices that is not subject to the same range of necessary preservation conditions required by macrobotanical evidence, nor the problems of contamination and ambiguity of transport that plague pollen analysis (phytoliths will travel, of course, if the sediment they are deposited in travels by wind or water, but this is often visible in surface degradation patterns; Madella 2011). There are some conditions which may affect phytolith preservation, primarily in terms of soil chemistry: alkaline soils above pH9, can cause phytolith dissolution, although grasses and sedges seem to be more robust than other phytolith types (Piperno 2006:19-22).

2.5.2 Phytolith Sampling Methods

Phytolith sampling methods were unfortunately but necessarily undertaken differently at each site studied in this dissertation. At TFK, sampling was undertaken systematically starting in 2014, including vertical and horizontal sampling under my own design and supervision. Additional samples were extracted from bulk sediment taken during previous excavation seasons. At Sidon, this was not possible; samples were taken instead at the discretion of the excavators when they encountered contexts that they thought were likely to contain significant botanical remains. Often these samples were taken initially as bulk sediment samples and then extracted in smaller quantities for pollen and phytolith analysis by the excavators later, although records for this process are not detailed.

At TFK, horizontal random sampling was employed across exposed surfaces such as floors and streets. Vertical sampling was conducted in cross-sectioned pits and middens and on the final vertical section of each excavation unit (excluding large stone fills). Additional point samples were taken from specific contexts generally high in plant-use, such as hearths, middens, and pits. Most samples were collected using a Marshalltown leaf trowel specifically for the purpose, cleaned with distilled water in between each sample collection, although some samples were collected with normal excavation trowels cleaned before and after with distilled water. Samples were approximately 20 grams in size, and were placed from the leaf trowel into ziplock plastic bags that were labelled and placed into another sealed ziplock bag. An additional paper label was placed in between the two bags, sealed inside the exterior bag. All samples were then sealed in Tupperware storage containers and shipped via the Department of Antiquities of Lebanon directly to the Environmental Archaeology Lab, under the direction of Dr. Arlene Rosen, at the University of Texas-Austin (UT-Austin). This dissertation presents the evidence from storage compartment and installation contexts, as well as a generalized overview of currently processed samples, but is not representative of the entire range of samples collected (as that is beyond the scope of a doctoral dissertation). The additional samples will be analyzed in the future as a series of articles.

The samples from Sidon arrived at the Environmental Archaeology Lab at UT-Austin via their original analyst, Dr. Anke Marsh of University College London. Dr. Marsh generously agreed to share the processing and analysis with me for my dissertation, and future publications will be in coordination with her work. However, neither Dr. Marsh nor I received detailed context or sampling protocol information about any of the samples provided by the excavation, and many of the samples we received were much larger than is ideal for phytolith sampling, requiring secondary extraction of random smaller quantities in the lab. I was able to travel to the Sidon excavation in 2016 and photograph the hand-written excavation records for the contexts from which the samples derive; this is the only existing information available for them. I have also been in contact with the director of the Sidon excavation, Dr. Claude Doumet-Serhal, and several of her assistants and collections managers, who have given me some additional information through personal communication. The ambiguity of contexts and/or dating is discussed as the data is presented in the following chapters.

2.5.3 Phytolith Processing and Counting

Phytoliths were extracted from the sediments following Rosen's (1999) protocol, which employs a series of techniques to remove carbonates, clays and organics, before extracting the phytoliths (See Appendix One). This method is the standard protocol in the phytolith laboratories at the Institute of Archaeology, University College, London and the University of Texas at Austin, and is an Appendix Two and largely non-hazardous protocol. The only dangerous chemical used is diluted Hydrochloric acid (HCL). First, the sediment was sieved though a 0.25 mm sieve to remove the coarse sediment fraction. A sample of approximately 800 mg was weighed using an analytical balance and then taken for analysis. The samples were placed in clean 50 ml PVA centrifuge tubes and treated with 30 ml of 10% HCL to remove the pedogenic carbonates. Once the samples stopped reacting, indicating the removal of the carbonates, the samples were washed in reverse osmosis (RO) water, before centrifuging for 5 minutes at 2000 rpm to concentrate the phytoliths and sediments at the bottom of the tube. The suspense was then poured off and this was repeated twice more to remove all the acid. To disperse the clays, 15-20 ml of sodium hexametaphosphate solution (lab grade Calgon 5% and distilled water 95%) was added to the sample. The samples were then poured into tall beakers (400 ml) and RO water added to a height of 8 cm. The samples were then mixed thoroughly with RO water and left to settle for 1 hour and 10 minutes. After settling, all of the particles larger than clay particles (~2 microns), including the phytoliths, should be resting at the bottom of the column, while the clay particles remain in suspense. The water and clay mixture was then poured off carefully, making sure to not disturb the coarse fraction with the phytoliths. RO water was then added to a height of 8 cm and the samples were again mixed thoroughly, and allowed to settle for 1 hour more, before being poured off carefully. Importantly, not all of the water gets poured off because this would result in the loss of some of the phytolith sample. The water is poured off only to a height that does not disturb the sample at the base of the water column. This settling process was repeated until the water was clear. Critically, the height of the water column (8 cm) and the time left to settle (1 hour and 10 minutes, then 1 hour subsequently) has been calculated according to Stokes' Law, which is an equation that solves the settling velocities (settling time) of small spherical particles in a fluid medium. The last of the water was then pipetted out, before the samples themselves at the bottom were pipetted into ceramic crucibles (~10 ml) and left to dry in the drying oven at <50°C before the organic removal step. Once dry, the organic matter was removed by dry ashing the samples in a muffle furnace for 2 hours at 500°C. Once cool, the phytoliths were then extracted from the remaining fraction using density separation. A sodium polytungstate (SPT) solution (with distilled water) calibrated to 2.3 specific gravity was used to separate the phytoliths from the heavier minerals. The samples were transferred from the crucibles into clean 15 ml PVA centrifuge tubes containing 3 ml of SPT and centrifuged at 800 rpm for 10 minutes. Since phytoliths have a specific gravity range between 1.5-2.3 (Prychid, et al. 2004:380), the phytoliths float in the heavy density liquid, while the heavier particles drop to the bottom of the centrifuge tube. The ‘pellet’ of phytoliths at the top of the suspension was then poured into a clean 15 ml PVA centrifuge tube. RO water was then added to lower the specific gravity of the solution and the sample was then centrifuged at 2000 rpm for 5 minutes to concentrate the phytoliths at the bottom of the tube. The SPT and water dilution was then poured off and recycled, and the phytoliths washed twice more to remove any residue from the SPT. The clean phytoliths were then removed from the tubes by pipette and placed in small weighed glass beakers. Once dried and weighed, a sample of approximate 2 mg was mounted on slides in Entellan.

The phytolith slides were counted at 400x magnification using a transmitted-light microscope. A minimum of 300 single cells and 50 multi cells were counted on each slide. The absolute counts for each phytolith type was calculated using a modified method outlined by Albert, et al. (1999); Albert and Weiner (2001). The results are expressed as number per gram of sediment. The morphologies identified are described according to the ICPN protocol (Madella 2011), as well as Rosen’s multi-cell husk terminology (1994).

2.5.4 Ground Stone

The category of “ground stone tools” includes lithic objects that were manufactured and/or used primarily via the kinetics of percussion, pounding, pecking, grinding, abrasion, polishing, etc. (Wright 1994; Adams 2014; Dubreuil and Savage 2014; Dubreuil et al 2015). The terms “macrolithic tools” or “nonflint implements” are also sometimes seen as interchangeable terms for these artifacts (Adams et al. 2009). Common ground stone tool types include hammerstones, abraders, grinding tools (e.g., grinding slabs/querns/metates used in conjunction with handstones/manos), as well as pounding (e.g., mortars and pestles) and cutting (axes and adzes) tools. Syntheses by Wright (1992b) in Southwest Asia, Adams (2002) in the American Southwest, de Beaune (2000) in Europe, and Dubreuil et al's general overview (2015) have emphasized that ground stone assemblage composition often varies substantially through time across geographic areas. For instance, cupmarks, anvils, hammerstones, and pounders appear well represented in early prehistory (Leakey 1971; Willoughby 1987; Goren-Inbar et al. 2002; Mora and de la Torre 2005), whereas sets of grinding slabs—handstones (also known as metates and manos) and other grinding implements make their earliest appearance in South Africa (McBrearty and Brooks 2000; Klein 2009, p. 537; Henshilwood et al. 2011) early in the Middle Stone Age (c. 300 ka and 50 ka following Klein 2009). Mortars and pestles emerged later; some of the earliest examples derive from the Upper Paleolithic period in Europe (43–11 ka, following Klein 2009, p. 666) and the Early Epipaleolithic (23.0–14.6 ka cal. BP, following Maher et al. 2011) in Southwest Asia (Semenov 1964, p. 134; Bar-Yosef 1980; Wright 1992, 1994; de Beaune 2004).

Ground stone assemblages generally trend towards larger and more varied assemblages during the late Pleistocene–Early Holocene, although some recent studies suggest that they appear even earlier in Australia (Geneste et al. 2012) and Japan (Takashi 2012). This corresponds to the Epipalaeolithic and Natufian, which has been considered a "transitional phase between hunter–gatherer and farmer adaptations" in Southwest Asia in general, and the Levant in particular (Dubreuil 2004; Dubreuil et al 2015). During this period, a significant increase in the relative abundance and typological diversity of ground stone tools (Wright 1992a, 1994) are often used to support theories of intensified plant exploitation during this time (Bar-Yosef 1980, 1981). Ground stone technologies multiply rapidly after the Neolithic, including those related to metallurgy, the stabilization of querns into a solid platform, the invention of the hopper mill and rotary quern (in Southwest Asia, the latter does not occur until the Middle Bronze Age), as well as presses for the extraction of oil, and the development of water and wind-milling industries (Lidström-Holmberg 1998; Curtis 2001; Alonso Martinez 2002; Treuil 2002; Delgado-Raack and Risch 2008).

It is the close relationship in narratives of Levantine socio-complexity that drew me first to the study of ground stone, and especially the way in which they are drawn upon to bolster narratives about human-environmental relationships, despite the fact that direct evidence for their functional roles in those relationships remain few and far between. This research therefore puts direct evidence from life-history and use-wear analyses of ground stone assemblages at TFK and Sidon into conversation with direct phytolith evidence for plant use at those sites. This approach seeks to articulate the ways in which empirical observations of overlap between stone and plant pathways can give us better insight into the ways in which EBA communities related to their shared geological and botanical landscapes.

2.5.5 Ground Stone Use Wear

The life history of a ground stone tool can encompass many stages (e.g., Nierlé 1983; Wright 1992; Dubreuil 2002; Adams 2002; Baysal and Wright 2005; van Gijn and Verbaas 2009; Dubreuil and Savage 2013) including, but not limited to raw material procurement, manufacture, primary, secondary, and further use, recycling as a new tool type (secondary manufacture), discard, and postdepositional processes. The reconstruction of the life history of a tool partly relies on the ability of the analyst to identify various types of wear on a tool and to organize them in a sequence according to their relative chronology. This can be achieved by looking for zones where different types of wear overlap. However, reconstructing the life history of an artifact based on use–wear is complex, as some of the stages of use can be difficult to isolate. In particular, distinguishing multifunctional from multiple-use or reused objects (sensus Adams 2002; Table 7.1) is challenging when distinct types of nonoverlapping wear are identified on an artifact. Using broader categories (e.g., evidence of multiple use or evidence of recycling) appears often more appropriate.

Use-wear analysis is based on tribology, which is the study of the ways in which materials transform each other through friction (primarily developed in engineering) and to identify specific patterns of physical and chemical transformations through macro and microscopic observation (Semenov 1964, Keeley 1980, Adams 2002b; Procopiou 2004). Semenov's (1957) pioneering work on ground stone use–wear included an analysis of axes, adzes, mortars, pestles, and abraders. Before this, most use wear studies had concentrated on flaked flint tools. Studies exploring use–wear formation on ground stone as a unique category with its own possibilities and limitations only expanded in the decades following Semenov's 1964 book on the topic. From a tribological perspective, wear can be defined as "a continuous damage process of surfaces, which are in contact with a relative movement" (Shizu and Ping 2012, p. 263). Drawing on tribology, Adams (2002, pp. 27–33) defines four processes of wear formation for GST: adhesive wear, which results from the attraction between contacting surfaces at the atomic level (Bahadur 2012, pp. 6–2); fatigue wear, the crushing and fracturing of rock grains by the pressure of contact; abrasive wear, the gouging and scratching of a soft surface by the asperities of a harder surface; and tribochemical wear, a buildup of chemical reaction products created through the interaction of the two surfaces. Each process leaves distinct patterns on the surface of the stone which can be used to reconstruct the contact environment associated with the use-context of the tool (Adams et al. 2009; Table 6.2).

I use macro and microscopic analysis of grinding stone surfaces, following the protocol established by Dubreuil and Savage for macroscopic and low-magnification microscopy (Dubreuil and Savage 2013). The use wear observations were undertaken at the American University of Beirut using an Olympus BXFM-F trinocular microscope with an interchangeable metallurgical stage for incidence light observation. Photographs were taken with my Nikon DSLR camera; multiple photographs at micro-scale variations were taken of each surface and scale adjusted using Helicon Focus software. Reference collection materials were produced using locally-sourced stones and experimental processing; surfaces were recorded for natural, eroded, and worn via a range of processing techniques (further described in Chapter Five). Surfaces produced through experimental processing of different stone surfaces is also an important component of use wear analysis, as the micro-composition of different stones can greatly effect the wear patterns encountered. Experimental studies have shown, however, that the transformations that occur through processing varying textures can be Appendix Twoly patterned (Doubreuil 2002, 2009; Adams 2002b; Buonasera 2013). Research combining use wear, residue analyses and experimentation has revealed much about the range of materials processed with ground stone, the mechanics of processing, and the ways in which different kinds of use appear over time (e.g., Hayden 1987; Adams 1989, 2002a-b; Fullagar 1993; Dubreuil 2002; Procopiou and Treuil 2002; Hamon 2006; Risch 2008).

In my macro-analysis of the assemblages, I follow Karen Wright (Wright 1992; Wright 2008; Wright 2014) in her suggestion that the ground stone craft industry, considered as such, can give us broader insight into structural organization of various technologies within a settlement. The classification system used here is based on that proposed by Wright (1992; see also Damick in Genz et al 2009) for Levantine ground stone assemblages. Terminologies used generally conform to Wright's suggested glossary, with a few notable exceptions: the distinction between "grinding slabs" and "querns" has been dissolved, and "grinding slab" used to refer to all stationary stones in a paired milling set, as use-wear traces suggest that these stones were used for both rotary and lateral grinding at Tell Fadous-Kfarabida. "Mobile/stationary," rather than "upper/lower," are the preferred adjectives to describe the relative roles of paired processing tools.[13] Additional classifications have been preliminarily added where no existing terminologies were suitable.

The processes used to clean ground stone surfaces before use wear observations are recorded can have a great impact on the reliability of those recordings – hard brushes can leave their own abrasive tracks, whereas too soft brushes can leave inhibiting dust particles in the interstices of the stone. A balance must be struck as well between the danger of rinsing away possible residues and getting a clean enough surface to observe use traces. Various cleaning procedures have been compared experimentally (Dubreuil 2002, 2004; Byrne et al 2006), and during my own experiments in Dubreuil's use wear lab at Trent University, I determined that a regimen of spot-cleaning stones with distilled water and a regular soft toothbrush was sufficient for low and high magnification observations. Occasional sediment particles were further removed with a needle when they blocked unique observation areas. I first took residue samples of selected spots on the stone surfaces using distilled water and a glass pipette, after agitating the surface with the water and a needle. Then I further cleaned the sampled spots with distilled water and a toothbrush for use wear observation. The entire surface was rarely cleaned, even though that meant the stones required more careful handling, because I hoped to preserve other possible

[13] The "mobile/stationary" combination refers more generally to the use potential of the artifacts, and is used widely in French ("courant/dormant") writing, thus bridging these bodies of research; the latter is particularly useful in the archaeology of Lebanon.

surface areas for possible developments in residue sampling. At Sidon, many of the stones had already been cleaned prior to my arrival. For the use wear preliminary study presented here I selected ten stones that had not been cleaned. This meant that while I was unable to be as selective as I would have liked about the provenience of the stones sampled, I was able to at least assure observation surfaces that had not been previously treated.

2.6 Summary

The following chapters explore the phytolith and ground stone evidence for storage and resilience at EBA Sidon and TFK, first in the land, then on the site, then in the tools. It is a study built on a series of long and varied intellectual traditions and literatures that are only starting to emerge together as complex, full landscape approaches producing and theorizing a range of new data sets. The existing evidence is complex and the nature of living in a changeable and volatile world is such that we are constantly having to recalibrate and reassess our data and its interpretations. This dissertation offers a path forward that attempts to build on the strengths of past environmental archaeologies while offering new directions for understanding why and how the landscapes of EBA Lebanon were, in some ways, so unique to their region and time. In doing so, I hope that it offers some new directions as well for understanding how our own societies might readjust our sense of resilience in relation to our own changing environments, politics, and climate.

Chapter Three

Stored Evidence: Sample Descriptions

This chapter offers a full list and description of the sediment samples processed for phytolith analysis and presented here. Unique, consecutive Lab Numbers were assigned to each sample as it was processed and in the order it was processed. Where there are gaps in the Lab Numbers, the missing numbers were processed but not ultimately counted for this study. The slides will be preserved for future work. This is intended to provide context for the samples discussed further in the rest of this text.

3.1. Tell Fadous-Kfarabida

Lab Number	**Field Number**	**Context notes**
TFK-15-2	310/295.1322	Context 2362; last archaeological fill layer, clean 4th millenium assemblage, in Bldg 4 northwest corner
TFK-15-3	310/295.1265	Context 2350; fill adhering to full ceramic bowl profile in NE corner of Room 6 possibly associated with floor 2337 as it slopes down under the fill
TFK-15-4	310/295.1252	Context 2350; fill under plaster floor 2337 - SW corner (with charcoal concentration) in Room 6

TFK-15-5	310/295.455	Context 1764 EBIV Pit 1761 - lower part of bottom fill
TFK-15-6	310/295.456	Context 1764 EBIV Pit 1761 - upper part of bottom fill
TFK-15-7	310/295.457	Context 1763 EBIV Pit 1761 - lower part of second fill
TFK-15-8	310/295.458	Context 1763 EBIV Pit 1761 - upper part of second fill
TFK-15-9	310/295.459	Context 1762 EBIV Pit 1761 - lower part of top fill
TFK-15-10	310/295.460	Context 1762 EBIV Pit 1761 - upper part of top fill
TFK-15-11	285/380.89	Area III PROFILE: TEST TRENCH W-FACING ashy layer under south wall
TFK-15-12	310/295.1117	Context 2334; EBIII floor context, packed earth and pebbles
TFK-15-13	310/295.1120	Context 2335; western room EBIII ashy silty floor below fill 2329
TFK-15-14	310/295.901	Context 2314; from floor in kitchen, ashy lens in the west by 2343

TFK-15-15	310/295.903	Context 2314, from floor in kitchen, SE corner,next to articulated vertebrae and sherds by 2343
TFK-15-16	310/295.957	Context 1795; EBIII storage room in Bldg 4, from SW bin/container at the base
TFK-15-17	310/295.958	Context 1795, EBIII storage room in Bldg 4, ash in middle of bin
TFK-15-18	310/295.959	Context 1795; EBIII storage room in Bldg 4, from base of storage bin
TFK-15-19	285/380.126	Context 4127; Area III surface with plaster and shell concentrations; from SW corner on plaster
TFK-15-20	285/380.261	Context 4043; Area III street surface
TFK-15-21	310/295.146	Pit 716
TFK-15-22	290/305.332A	Pit 716 upper fill high
TFK-15-23	290/305.332B	Pit 716 upper fill low
TFK-15-24	290/305.235A	Pit 716 mid fill high
TFK-15-25	290/305.235B	Pit 716 mid fill low
TFK-15-26	290/305.360	Pit 716 lower fill
TFK-15-27	290/305.361	Pit 716 lower fill

TFK-15-29	310/295.1252B	Context 2350; fill under plaster floor 2337; EBII surface NE corner
TFK-15-31	310/295.580	Context 1767, EBIII storage room west of 1795
TFK-15-32	310/295.581	Context 1767, EBIII storage room south of 1795
TFK-15-33	310/295.582	Context 1767, EBIII storage room east of 1795
TFK-15-34	310/295.589	Context 1768, from feature 1757
TFK-15-35	310/295.593	Context 1770, maybe tannour structure walls
TFK-15-36	310/295.1280	PROFILE - top fill of ashy midden - the context was all recorded as one when excavated, but in section multiple fill layers are clear
TFK-15-37	310/295.1281	PROFILE - second fill of ashy midden - the context was all recorded as one when excavated, but in section multiple fill layers are clear
TFK-15-38	310/295.1282	PROFILE - third fill of ashy midden - the context was all recorded as one when excavated, but in section multiple fill layers are clear
TFK-15-39	310/295.1283	PROFILE - fourth fill of ashy midden, with and around small boulders
TFK-15-40	310/295.1284	PROFILE - fifth fill of ashy midden, high gravel content

TFK-15-41	310/295.1285	PROFILE - sixth fill, or possibly base of ashy midden - yellowish brown, poorly sorted sandy sediment
TFK-15-42	310/295.1026	Context 2343; in ashy deposit
TFK-15-43	310/295.583	Context 1760 EBIII Bldg 4 floor, north
TFK-15-44	310/295.584	Context 1760 EBIII Bldg 4 floor, south
TFK-15-45	310/295.1266	Context 2343, Bldg 4, ash fill of south compartment in Room 5, below 2326
TFK-15-46	310/295.1027	Context 2324, kitchen surface, under ashy deposit
TFK-15-47	310/295.1293	Context 2356, from the installation to the south of the bench slab, likely the upper fill, soft fine well-sorted brown silt, cut into 2358
TFK-15-48	310/295.1295	Context 2358, from the installation area to the south of the bench slab, likely the first primary installation fill then cut by brown fill 2356
TFK-15-49	310/295.1344	Context 2353, north floor in western room
TFK-15-50	310/295.1346	Context 2358, south floor in western room
TFK-15-51	310/295.514	Context 1726 Floor - W; lower level of floor, above ashy plaster

TFK-15-52	310/295.515	Context 1726 Floor - N, edge of lower floor/plaster-ash
TFK-15-53	310/295.516	Context 1726 Floor - S, edge of lower floor, plaster/ash
TFK-15-67	310/295.948	Context 2317, from corner room; W edge under installation
TFK-15-68	310/295.949	Context 2317, from corner room; NE corner charcoal concentration
TFK-15-69	305/295.76	Context 606, floor of Building 4, Room 3
TFK-15-70	305/295.52	Context 907, upper dumping fill in Building 4, Room 2
TFK-15-71	295/295.196	Building 1, Room 1, storage bin, Phase III
TFK-15-77	285/295.296	Phase II floor, around grinding stone on floor 247
TFK-15-79	295/295.228	Building 3, Phase IV upper floor 824
TFK-15-82	310/295.1755	fill of pit 2415, probably early EBIII
TFK-15-83	310/295.1785	upper fill of pit in southern part, below floor 2420 in Room 5
TFK-15-84	310/295.1795	lower fill of pit below the floor in Room 5
TFK-15-85	310/295.1817	upper fill in northern part of pit in Room 5

TFK-15-86	310/295.1845	fill from middle of wall of large pit in Zusanna's room
TFK-15-87	310/295.1865	large refuse pit 2132 in sounding; probably EBII, possibly early EBIII
TFK-15-88	310/295.1873	fill below possible floor 2430 in sounding, mostly Chalco sherds in deposit
TFK-15-89	310/295.1879	relatively clean Chalco level, brown sediment deposit with almost entirely Chalco sherds below Zusanna's pit
TFK-15-90	310/295.1880	lower level of Chalco deposit in Zusanna's room, may be mixed with geological layer below
TFK-15-98	310/295.1682	possible hearth, or at least ashy context
TFK-15-99	310/295.1530	in between installation 2369 and wall, area with multiple burning patches, this one with charcoal, white ash, and charred olive pits; check sketch
TFK-15-100	310/295.1683	possible hearth, northern part
TFK-15-101	310/295.1529	in between installation 2369 and wall, area with multiple burning patches, this one with charcoal, white ash, and charred olive pits; check sketch

TFK-15-102	310/295.1411	base of storage compartment 2343 in north kitchen room, small rectangle of very distinct ashy plaster at the bottom of the compartment, called "matting" by excavators
TFK-15-104	310/295.1441.2377	south part of floor 2377
TFK-15-105	310.295.1520	under grinding slab 2357 from southern part of western room
TFK-15-106	310/295.1523	floor in central part of western room
TFK-15-107	310/295.1666	plaster patch in north of floor
TFK-15-116	290/295.188	Building 1, Room 2, floor 522
TFK-15-117	300/300.33	Phase IV floor 2106
TFK-15-123	310/295.1846	Geological layer below EBII pit
TFK-15-124	310/295.1402	Phase III surface
TFK-15-125	310/295.1789	floor above the pit

3.2 Sidon

Descriptions taken from excavator's notes, and reconstructed to contexts and spatial arrangement from excavation notes and drawings.

Lab Number	Field Number	Context notes
1	CS.929.2497	EB Pit 2501 room 10
2	CS.940.2508	EB plaster floor, Room 2 (wheat patch)
3	CS.953.2500	EB white plaster below Room 10
4	CS.936.2508	EB plaster floor, Room 2 (wheat patch)
5	CS.941.2508	EB plaster floor 2508
6	CS.944.2508	EB plaster floor, Room 2 (wheat patch)
7	CS.944.2508/9522	EB plaster floor, Room 2 (wheat patch)
8	CS.913.2472	EB grey floor
9	CS.933.2510	Below EB mudbrick room 10
10	CS.918.2475	EB white plaster, soil Room 6
14	SME.238.2197	EB cobbled feature
16	SME.212.2057	EB burnt fill
17	SME.217.2049	EB east of post pad
18	SME.215.2090	EB fallen mudbrick
21	SME.220.2119	EB burnt deposit
22	SME.229.2121	EB charcoal layer in 2120
23	SME.235.2191	EB ashy deposit pit 2208
24	SME.219.2113	EB clay layer
25	SME.221.2138	EB ash? Deposit
26	SME.223.2119	EB burnt deposit

27	SME.231.2162	EB charcoal deposit
28	SME.233.2178	EB burnt deposit
29	SME.216.2097	EB surface
31	SME.234.2182	EB fill of pit 2159
33	CS.955.2514	EB fill of mortar, Room 2
37	CS.972.2536	EB burnt wheat, store room 10
38	CS.975.2544	Chalco/EBI fill of large pit, Room 6
43	SME.222.2119	EB burnt deposit
44	SME.225.2141	EB fill of pit
45	SME.230.2121	EB charcoal layer in 2120
46	SME.236.2192	EB pit 2208
47	SME.237.2195	EB cobbled feature
48	SME.239.2182	EB fill of pit 2159
65	SME.45.1213	EB episode of demolition
66	SME.44.1213	EB episode of demolition
67	SME.47.1225	EB charcoal in room
68	SME.48.1221	EB burnt collapse
69	SME.53.1248	EB burnt spread?
70	SME.54.1241	EB clay surface in room
71	SME.56.1253	EB fill inside jar 1133
72	SME.57.1264	EB backfill of EB pit with fish bones
73	SME.59.1259	EB burnt mudbrick collapse

74	SME.60.1268	EB burnt spread?
75	SME.61.1266	EB occupation surface
76	SME.62.1271	EB backfill of EB pit
77	SME.63.1278	EB pit
78	SME.64.1269	EB occupation surface
79	SME.65.1279	EB burning of structure

Chapter Four

Storing Balance: The Preserved Plant Technologies of Storage Bins

"The plowmen lifted their heads,

the sowers of grain their backs:

gone was the food from their bins,

gone was the wine from their skins,

gone was the oil from their vats."

Kirta, Tablet X Column X (Coogan and Smith 2012: 71)

4.1 The Storage Bin

There may be no more iconic indicator of the kind of momentous societal transformations in the prehistory of Southwest Asia than the modest storage bin. For such an apparently simple idea, the ability of entire societies to flourish, to make adequate predictions and provisions for the future, for leadership to remain stable, all depended on the proper functioning and maintenance of the bin. In the above quote from the Ugaritic tablets, the great Canaanite king Kirta has fallen ill, and in doing so has failed to keep his people's stored provisions intact, which forms a central crisis of the story. This is repeated in the Baal Epic when Baal is gone to the Underworld and the harvest fails, so the stores are consumed. Concern over the fragility of the abandoned storage compartment is echoed in these ways through the later Canaanite texts; the antiquity of that concern is seen in the archaeological record, as one of the first and most persistent features to appear archaeologically with the emergence of complex aggregated societies are increasingly sophisticated and extensively maintained storage systems.

For many societies, stored agricultural products play an important role as a "buffering mechanism" that mitigates the negative impact of variations in climate and agricultural productivity. Agricultural products can be stored during years of plenty to provide a "buffer" for societies during less productive years. In many cases, however, this type of planning does not serve the interests of the community as a whole, but rather becomes part of emerging systems of domination and institutionalized inequality. Control over what plants are available, to whom, and over what time span has frequently been an Appendix Two tool wielded by elite groups or individuals attempting to establish political and/or economic dominance regimes (Tate Paulette 2015: 39-40; Halstead and O'Shea 1989: 3-4; D'Altroy and Earle 1985: 192; Stein 1994: 41-3l; Halstead 2002: 68-9).

Long before the EBA societies examined here, the people of the late Epipalaeolithic and the Neolithic, were using storage technology that has been seen as one of the key developments through which hunter-gatherers were first able to use the same important places repeatedly and more intensively over time – for instance, Boyd (2006) argues that storage is part of a whole suite of practices that Natufian people took up in their production and maintenance of complex social landscapes. It is often proposed that storage had a second important role in the eventual establishment of more permanently sedentary ways of living, as they were bolstered by the long-term risk management storage provides (Kuijt 2008; Carver 2012; Hodder 2018). Except for a few exceptions (for instance, at Jericho: Kuijt and Finlayson 2009), evidence for storage in the

Neolithic Levant tends to take the form of small-scale, household-based pits and bins, however, rather than large-scale centralized communal storage (Kuijt 2008, 2009).

In the Chalcolithic-Early Bronze Age, storage technologies were developed further to provide for larger quantities stored, greater precision in long and short term use, and to produce different end effects on the materials being stored. This is the time when "surplus" – the ability to produce enough more than the society needs, through specialization and intensification of particular kinds of agriculture, allowed for societies to use the extra for something else. This often implies a re-orientation of society away from broad-spectrum subsistence production and towards a specialized, trade-dependent economy. This is executed via the amassing of specific surplus resources (such as wheat, olives, or grapes/wine, in the Mediterranean context) under a centralized administrative authority, which controls both the local distribution of that resource, and its trade use in procuring other kinds of resources that are not produced locally (such as fruit, copper, basalt, or fineware). Through the restriction of different trade items to specific groups, we see the emergence of local hierarchies through access to new kinds of material expression.

At the root of this, again, is the storage bin. Iconic examples of massive surplus storage in the Chalcolithic-EBA come from the storage silos in the Southern Levant, such as those at Khirbet Kerak (Mazar 2001; Greenberg et al 2014), Tell Tsaf (Rosenberg et al 2017) and Amaziya (Milevski et al. 2014), as well as palatial complexes such as Tell Yarmouth (Miroschedji 1999). Researchers of the Southern Levant are beginning to investigate the symbolic as well as economic potency that these storage systems held for the complex aggregated communities of the EBA (Garfinkle et al 2009; Rosenberg et al 2014). In Syria, the palatial storage structures at Ebla have been linked by their excavators to craft production industry and secondary food transformation techniques (i.e., transforming bones, shell, and horticultural waste products into tools or decorative objects), demonstrating the way in which storage bins are linked to the broader socio-economic development of the settlement at large (Marchetti and Nigro 1995).

However, iconic though the storage bin may be, our understanding of the development and application of specific storage technologies in Lebanon remains limited, due to a variety of factors. Partly, the political environment of Lebanon over the course of the 20th century that inhibited all archaeological research obviously played a role, as detailed reconstruction of sensitive but not necessarily spectacular structures like storage was not a priority in the post-war years. Another significant factor is preservation quality, as the sub-humid climate and high calcium carbonate content of the Lebanese littoral have rarely left the kinds of macro-scale evidence that is seen in more arid regions, such as Eastern Anatolia, the Southern Levant, and Greater Syria, particularly when the storage structures are not stone-lined (which, as we will see below, they most frequently were not). A final consideration may be the proper identification of storage compartments as such; so far, there are no large-scale free-standing silos or granaries from EBA contexts in Lebanon, as there are in the Southern Levant, and often EBA architecture has been fragmented and obscured by later construction. Systematic, multi-year excavations at sites like Tell Arqa, Sidon, and TFK have begun to change this picture, and with the introduction of micro-scale techniques, such as phytolith analyses, we are able to uncover evidence for Early Bronze Age storage in Lebanon on an entirely new scale.. This chapter presents the results of phytolith analysis from the on-site storage facilities at TFK and Sidon.

4.2 Tell Fadous-Kfarabida Storage

To refresh our understanding of the site history, excavations have revealed only limited remains from the early 4th millennium. After a hiatus, the site was rapidly reoccupied just after 3000 BCE, when dense, multi-roomed residential structures appear separated by narrow, planned streets; limestone column bases inside the rooms likely supported wooden columns and upper stories, as attested in one room by the conflagration of a wood-beamed roof (Genz et al 2009, 2010, 2011, Genz 2012a). The site continued to grow and transform over two phases in the third millennium. First, the domestic architecture expanded and grew into two-story structures and a fortification wall was built around the settlement. Large-scale public architecture then replaced some residential buildings, and expanded directly upon other lower structures. The presence of cylinder seals, at least some locally produced, with parallels to Byblos evidences a linked administrative presence with that site (Genz 2012a). TFK during the EBA was around 1.5 hectares, making it a small but dense and clearly significant settlement for the area. Around 2500 BCE, it appears to have been largely abandoned in terms of year-round occupation; after another hiatus, only EBIV pits and eventually MB burials are found. This dating, however, clearly places de-urbanization centuries before the earliest affective range of the 4.2k arid event (Höflmayer et al 2014). In the second millennium, the site is reused as a burial ground, and recent excavations indicate possible further occupation as well, indicated by a rather massive wall (Genz et al forthcoming).

The macrobotanical assemblage is only well preserved for Phase III, which on its own gives only a snapshot of a moment in the human-plant history of the site, and is based on averaging bulk samples from a wide variety of contexts rather than specific activity areas. This snapshot suggests an agricultural economy oriented towards specialized production of wheat (emmer) and olive, a distinct but not unique situation for an Early Bronze Age aggregated society in Southwest Asia generally (Riehl and Cakliklar in Genz et al 2009). Riehl notes that EBA settlements throughout the Levant seem to have specialized in their staple crop production by the third millennium BCE, with TFK and Tell Yarmouth, for instance, specializing in emmer wheat and olive, while Megiddo and Tell Nebi Mend produced barley and emmer (Riehl 2009, 2010, in Genz et al 2016). The quantities of wheat and olive represented by the TFK macrobotanical data easily qualify as surplus production for such a relatively small settlement. Therefore the interpretation of the site has been that it was a second or third-tier administrative center managing a specialized agricultural economy, likely for export to Byblos and beyond in the context of an interconnected Levantine network of specialized crop production and trade.

If this is true, then indeed, understanding the storage practices on site are a key to understanding the relationship of the site's crop management to this larger network. Understanding the settlement's role in this regard further helps us to broaden our understanding of the strategies for landscape niche curation, and to put them in a regional context. This is where the phytolith evidence becomes particularly relevant.

4.2.1 Earliest storage compartments at TFK

The earliest evidence for storage at TFK comes from Phase II. Before this, we have so far no direct evidence for storage on the tell area. This could of course be related to the limited exposure of the site, or the destruction of one third of the site area prior to archaeological intervention. In any case, if there were storage installations earlier than Phase II, it was in a different area and related to different structures than we see in the later occupation phases. Without further exposure of the earlier levels for context, it would be difficult to assess such features.

Phase II storage installations come from two sources: household-based compartments in the residential structures such as Building 2, and pits in the lower levels of the building that eventually became the Phase III administrative building (Building 4) (**Figure 4.1**). I will begin with the series of Phase II-III structures making up this building complex.

4.2.2 Administrative Building Four

It is currently unclear whether the Phase II incarnation of Building 4 was in fact publicly or administratively-oriented or not, as discussed in Chapter Two. By Phase III, however, it most certainly was rebuilt on a larger scale, in some areas using the foundations of the Phase II structures, and appears to house primarily food and possibly drink processing areas associated with the large public building, Building 5. Building 4 was certainly at least a two-story and possibly a multi-story structure, based on the column bases and collapse layers uncovered in the rooms. What we are left with are largely the basement rooms, at least three of which (Rooms 3, 4, and 5), contained storage compartments. Some of these appear to have spanned Phase II and Phase III.

Our best representations of constructed storage compartments come mostly from the northwestern part of the building. In Room 4, there are at least three rectilinear compartments dug into the underlying Phase II levels of the structure, and partially lined with limestone cobbles and beach pebbles around the top (**Figure 4.2**). In Room 3, along the narrow northwestern extension of the room, there were at least two pit compartments aligned along the room's eastern wall, one rectilinear and one round but irregular, on either side of a large stone bench and in one case. A cache of grinding stones was next to the smaller, irregular pit compartment. These two were not stone-lined, and appeared directly dug into the sediment below (**Figure 4.3**). In Room 5, two rectilinear storage compartments were aligned adjacent to the southern wall of that room, lined with stone cobbles to separate them from the pebble glacis of the main room flooring (**Figure 4.4**). While all the compartments are partially stone or clay lined, their interior sides and bases are not well preserved structurally. The phytoliths, however, give us some insight into what the construction of these spaces originally looked like.

The diagnostic multi-cell phytolith types for the Building 4 storage compartments are presented in **Figures 4.5**. At first glance, the microbotanical results do not seem to show such high taxa specificity as the macrobotanical results. This is a function of the better preservation of a wide variety of typically underrepresented taxa. When we break these down, however, a fascinating picture of specific, calculated storage construction technologies begins to emerge.

4.2.3 Containing the Grasslands: Cereals and Wild Grasses

Figures 4.6-4.7 show the diagnostic grass husk multi-cells isolated for comparison, separate from the wetland and woody taxa. Barley and wild grasses make up a quite high percentage throughout the pit samples. The presence of cereal straw is fairly high in most Phase III storage contexts. The percentage of husks (indicating the presence of sheaves of grain) to total cereal count (including straw and leaf) is only between 40 and 50% across the board. This seems to show a very contradictory picture from the high wheat husk count that that we might expect from the macrobotanical results.

However, when we look at samples taken from the floor surfaces just next to the storage bins in Room 4, we do in fact see a significant predominance of wheat husk multi-cells. This suggests three things: first, that cereal grasses were being brought to site and stored in uncleaned sheaves that were processed piecemeal on site. This is the only way in which such strong, localized signatures of wheat husk appear on the floor surfaces, where they were processed, while mixed leaf, straw and low-level husks are in the storage bins, where they were stored but only left behind incidentally.

Second, the high proportion of weeds and cereal straw relative to inflorescence within the pits is also a possible indicator of animal dung, likely for fuel; ethnographic examples tell us that, whatever storage compartments were originally used for, they eventually become secondary repositories for general refuse. This situation therefore may indicate either secondary dumps of hearth refuse (and there are hearths in the vicinities, especially in Room 6), or intentional storage and use of dung cakes in some areas. Given the non-presence of spherulites, however, I tend to think that this is likely evidence of scattered post-use refuse dumping rather than a concentration of stored cakes. The floor surface areas surrounding the bins, on the other hand, probably represent spill-over from either depositing or removing grain that was actually stored in the bins: in the case of Compartment 1795, almost entirely wheat, and for Compartment 2343 wheat and barley, for instance. Floor surfaces in general would have been kept more clean of later refuse, as it was swept into the pits. This has been pointed out as a pattern also at Catalhöyük and Tell Zeidan, for instance (Rosen 1995, 2005).

4.2.4 Weaving the wetlands: Sedges and Reeds

When we reintroduce the probable wetland taxa to the analysis, the picture becomes even more interesting – the predominance of sedges and reeds throughout the site is significant. *Cyperaceae* appear in notably high quantities and ubiquities, both as multi-cells and as single cell cones, in almost every context so far analyzed. Although some sedges can grow in arid environments, the position of Tell Fadous-Kfarabida along the coastal plain and at the mouth of a river valley, along with the presence of moisture-loving taxa like *Phragmites* and *Setaria spp.*, strongly indicate a wetland origin.

It is most likely that the sedges and reeds in these contexts primarily represent non-food related plant use that was not the object of storage but rather its material infrastructure, such as flooring, matting, or basketry. In fact, in two storage bins (in Building 4, Phase III; **Figures 4.8 and 4.9),** the base layers revealed an extremely high peak of *Cyperaceae* relative to almost zero cereal husks, along with reeds and slightly more weedy grasses. One of these contexts was described by the excavators as "ashy plaster matting along base of bin." It is likely that this layer was not ash or plaster but a thin phytolith layer of decayed in-situ sedges at the base of the pit, as that is what dense phytolith deposits look like. Given the results of the analysis, it seems reasonable to reinterpret that layer as the dense residue of sedge and reed matting.

We can therefore think of these compartments as having been dug into underlying fill levels, partially stone or clay lined to shore up their walls, then lined again with a layer of sedge and reed matting before grain was added, either in baskets or as naked sheaves. In some cases, it appears that another layer of matting was placed on top to seal the compartment, while in other cases it is more likely that they were left open for easier access. Since these are intramural structures, their rectilinear shape makes sense, as a more efficient use of the interior room space, whereas the silo granaries in the southern Levant can be ovate as they are free-standing. It has been suggested for these silos that the rounded shape better protects the grains from pressure applied by sharp corners and flat wall surfaces; however, the matting would have smoothed these surfaces out and mitigated that problem, as would any baskets used to hold the grain (discussed below).

These high quantities of wetland taxa demonstrate the continuous exploitation of wetland micro-environments in the site catchment area even once it becomes an administrative center focused on the management of staple cereal crops. Whereas in the previous chapter, we saw the cyclical rise and fall of the use of wetland niches throughout the site occupation history, here we see a specific on-site context where those were put to use. Moreover, the matting in these contexts would have had to be frequently replaced, as they dried out and frayed. In some cases, they were used to seal the grain into an oxygen-free environment so that it would preserve for longer periods of time (discussed further at the end of this chapter). Once the seal was broken, the grain had to be used immediately or it would spoil quickly, and the bedding would have to be replaced to reseal the compartment. Perhaps we might think of cycles of storage construction and maintenance as one of the relevant factors in relation to cycles of wetland use, rather than strictly climate and risk-based patterns.

Equally significantly, these sedge and reed linings for storage structures seem to emerge in relation to the growth of the settlement as a staple crop administrative center. Along with the wheat and barley represented in the microbotanical assemblages, a large quantity of olive pits were recovered by the excavators. As these olive pits are always charred, it is likely that they arrived in their final deposition spots in a secondary use as fuel, after the olives were eaten or processed for oil. I therefore consider them representative of general presence and density of use at the settlement, but not as representative of the contents of the storage compartments. Although olives produce phytoliths and calcium oxalates, they do not produce diagnostic examples, and therefore it is not currently possible to confirm the presence or absence of non-burnt olives via phytolith record (Tsartsidou et al 2007). Olives also do not store well unless transformed into oil or preserved in oil or brine; until we retrieve more large storage vessels and are able to analyze them for their lipid content, we do not have the evidence to support large scale storage of whole olives. In any case, their increased present on-site over the course of the EBII-III aligns with the increase in wheat both over the site generally and along with the appearance of the storage compartments. So we see a settlement that is certainly engaging more intensively with a specialized staple crop industry focused on wheat and olive, but simultaneously, that industry depends on the maintenance of wetland niches in the landscape, and preservation of the knowledge to access and put them to use over time.

In summary, while the diversity of domestic and wild taxa in the pits at first glance appear to preclude their use as single product containers, the presence of almost exclusively wheat next to them paints a different picture. I suggest, tentatively, that the EBII-III storage compartments were originally lined with reed and sedge matting and used for storing uncleaned wheat and possibly sometimes barley. Over time, they subsequently became receptacles of debris that fell or was dumped into them, including dung fuel and hearth debris. In some cases, we may also have the case that dung cakes were actively stored in these containers, but the current evidence does not support that definitively. The implications of this for long and short-term storage planning is discussed at the end of this chapter, along with an assessment of implications for storage scale and capacity.

4.2.5 The latest storage contexts: the EBIV pits

As described elsewhere, the only contexts currently known from the Phase V occupation of the site are isolated pits (**Figure 4.10**). It is in fact a fascinating feature of the site that it is so retained in the local popular memory that even after it is essentially de-populated in the early-mid third millennium BCE, it remains in almost continuous use in different ways. The continuity of the material culture both within the site itself over its different occupation phases, and in comparison to local material culture at Byblos and Tell Arqa, strongly suggests that there is no major cultural disconnect, but rather a transition in the way the local landscape was occupied and how people used this central, and still important, place.

In Phase V, the use of the settlement site at TFK seems to be primarily for storage – perhaps related to specific events in some cases, in other cases likely over longer periods of time. There is some evidence, as well, as discussed in the previous chapter, that this occupation phase included some degree or reoccupation (or "squatter" occupation), including some rebuilding, of previous structures. Unfortunately, due to the destruction of much of the site, we will never know how widespread this reoccupation was, and whether it was intermittent or long-term.

Given the different nature of site use and occupation during this phase, the samples from these pits must not be understood as directly comparable with earlier samples from the site since they represent discrete activity episodes (although possibly multiple events deposited over time) and not the activities of long term residence immediately on site, and likely not associated with the same organizational centralization or scale in relation to staple crop production and management. Furthermore, there is some evidence for mixing of the pit contexts, likely both from natural causes and the effects of recent modern construction damage to the uppermost site levels. However, they are included here both because their results suggest storage intent, and because they remain some of the most important indicators of the way in which the site continued to be used throughout the increasingly arid late third millennium. The evidence presented here helps to clarify the possible kinds of plant technologies and storage practices that persisted on site even after primary occupation dispersed. The phytolith results from two EBIV cross-sectioned pits can be seen in **Figure 4.11.**

The first thing to note is that there is a markedly higher density of wheat husks in the EBIV pit samples than in the EBII-III samples. This indicates that even after the administrative function of the settlement declined, wheat cultivation continued in the area to the point that it could dominate the microbotanical assemblage, regardless of internal mixing.

This on its own is significant – it suggests that the kind of expansive cereal farming we have come to expect from the aggregated settlements of the Early Bronze Age is not, at least in this case, tied strictly to a particular formal kind of centralized settlement occupation. If a relationship of mobility between settlement, field, and wetlands was already extant,, then perhaps local administration did not require the maintenance of its monumental center so much as maintenance of its landscape knowledge, practices, and infrastructures. We might, perhaps, think of the monumental, walled center as more important in relation to the administrative center at Byblos than it was to local organization of resources, labor, and plant use. Since we also can see that the dispersal of centralized site occupation is not tied to the 4.2k "drought event," and that

that event clearly did not inhibit the continued growth and use of wheat in the settlement area, we might instead think of this de-centralizing movement in relation to a political reorganization of Byblos and its administrative centers[14], with very little local landscape impact.

The second point of note is that in the EBIV pits, cereal straw only occurs in the very earliest and latest deposits of Pit 1761 and in the earliest levels of Pit 716 (**Figure 4.11**), which again seems to be related to the structure of the pit itself, in the form of matting or packing with straw and mud. This effort and the choice of this particular technology certainly indicates storage rather than discard or symbolic deposition as the purpose of at least some of these pits. In general, sealing with straw is a technology directed towards longer-term storage, and often the preservation of grain for replanting, as discussed below. If these pits represented only the discard or post-facto deposition from single events, there would be no need to line them carefully with straw. If indeed long-term storage is indicated here, it would be particularly interesting, as it suggests that the pits represent the intent to return over time, and long-term investment in site activities, rather than sporadic events.

This underscores the possibility that centralized storage of cereal resources, and the techniques tying wetland and cereal resources together through storage thinking, was a strategy unrelated to larger regional settlement politics. While reeds and sedges may or may not have made up part of the structure of the pits themselves, they occur ubiquitously throughout the pit contexts, and their quantities demonstrate that the wetland taxa clearly continued to be in active use alongside cereal crops. This may suggest baskets that were removed over time, for instance,

[14] Byblos was destroyed by conflagration at the end of the EBIII, as described in Chapter Two; as I stated in that chapter, it is not my goal here to reinterpret why and how this destruction took place, whether by Amorites, Sargon, or internal affairs. Nonetheless, it was rapidly rebuilt and reoccupied, and that almost certainly would have included some reorganization of its administrative territory, as well.

leaving only low-level but ubiquitous phytolith evidence behind. This is the mark of resiliency that has characterized the settlement throughout its history – the ability to use new agricultural strategies to expand specialization of crops like wheat and olive while simultaneously maintaining long-standing knowledge of local wetland environments and relying on the integration of wetland foraging strategies into times of plenty, as well as times of stress.

We might in fact take these EBIV pits a step further, in putting them in conversation with the surrounding EBIV material from the site. It appears that there was some degree of non-subsistence related use of the site, including re-incorporation of the visible ruins of the EBIII structures (Genz et al 2018). Might we in fact begin to see the persistence of the site as a meaningful place, whose significance is maintained through practices that preserved memory of its past? In this sense, these pits store not only plants and ceramics, but in fact they store the memories of a place and its society that remained active through the volatile EBIV period.

4.3 Storage at Sidon

The storage situation in Sidon presents a picture that is in some ways quite similar, and in others markedly different from that at TFK. Sidon was, indisputably, a different kind of settlement than TFK, as discussed in detail in the preceding chapters. It should be repeated here (as discussed in Chapter Two) that the samples available from Sidon were far fewer in number and density than those from TFK, as I designed and executed the TFK sampling protocol, whereas sampling was undertaken much more informally at Sidon. When I came on board the Sidon analysis, some phytolith samples were already analyzed by Dr. Anke Marsh at UCL; while I will be collaborating with her to expand our understanding of the Sidon phytolith record in the future, her results were not available to me at the time of finishing this dissertation. We should therefore remember that the evidence from Sidon is still forthcoming and will undoubtedly become more clear as work progresses. Nonetheless, the results that we do have are enough for an interesting comparison and indeed, suggest some fascinating insights into stages of storage and processing at a larger EBA settlement.

4.3.1 The Earliest Storage Compartment

The only sample from the EBI transitional phase at Sidon comes from a pit below the EBII-III storage building. I use the term "storage compartment" extremely loosely in this case, as there was almost no phytolith record for the contents or construction of the pit and therefore its purpose cannot be known with certainty. It is not particularly surprising that there is not more extensive evidence for this period. The nature of excavating to the required depth to encounter fourth millennium remains is such that the horizontal exposure must be limited in a restricted urban area. Also, it seems quite evident that there were other settlements such as Sidon Dakerman nearby that were more intensively occupied during this time, before moving to Sidon itself. This is a common case seen in the Southern Levant, as well, where often EBI villages are abandoned and populations merge with larger neighboring settlements in the EBII. White et al. describe this situation at Numayra and nearby Bab ed-Dhra, for instance(2014). They attribute the abandonment of the former for the latter to unsuccessful agricultural strategies at one that led to its ultimate unsustainability, whereas the other managed its agricultural resources and labor more successfully, leading to increased aggregation for thousands of years. Unfortunately, however, as the single EBI sample from Sidon did not return a very dense or robust phytolith record, we remain in the dark about the nature of plant use during this time at Sidon until further early contexts can be sampled. For the time being we cannot be sure if agricultural strategy is what motivated the move in this case, but it is certainly worthy of future investigation.

4.3.2 EBII-III Storage Compartments

As is the case throughout Lebanon and indeed the coastal Levant, in the early third millennium BCE, known as the EBII, the settlement at Sidon began to expand and increase in density. Although the coverage of the modern city prevents us from knowing the true extent of the ancient settlement, it likely covered most of the central tell but does not seem to have extended beyond the tell limits, so was no more than 5-7 hectares.

In the mid third-millennium BCE, a large mud brick building measuring at least 20x12 meters and containing at least ten rooms was constructed in the central area of the tell of Sidon, resting on and replacing earlier architecture beneath it (**Figure 4.12**). The pottery (rolled rim platter jars and a zig-zag patterned jar being of particular note) indicate that it most likely was in use in the late EBII and mainly the EBIII (Doumet-Serhal 2006). It appears to have been used primarily as a storage facility, as several of the rooms were divided by large lime-plastered mud brick walls into rectangular compartments of approximately 2x3 meters each, that were almost certainly located in the basement of the large, multi-story building (Ibid). There are also several rooms with features of daily labor, such as hearths, grinding tools, and jars and bowls. The building was destroyed by a fire at the end of this period, as evidenced by a thick conflagration layer, which left entire burned deposits of grain macro-remains in its wake, along with layers of lime plaster used to extinguish the fire that sealed the contents at the time of destruction within (Doumet-Serhal 2006b; **Figure 4.12**).

The burnt, and therefore largely preserved, contents of these rooms are certainly of great interest. Not only does the range of consistently dateable EBIII pottery help secure the age of use of the building, but a great amount of charred grain was also recovered, primarily *Hordeum vulgare spp. distichum*, or two-rowed barley (De Moulins 2009), and *Triticum turgidum ssp. dicoccoides*, or emmer wheat (Sidon excavation notes, Doumet-Serhal pers. comm.). The macrobotanical evidence showed that a range of other plants were present but in very small quantities. Through the microbotanical analysis of this dissertation, I have been able to both expand the known range of other plants that were in the storerooms, but also their relationship to the plants present just outside and surrounding these storage compartments – this gives a much broader picture of large-scale staple crop storage that can only exist in relation to the availability of a range of other plants. It further shows that even at a site of significantly larger scale, that operated at a higher administrative level within the network of EBA coastal settlements, technologies related to plant use seem to still preserve some conservative patterns, just at an expanded scale. Although we think of larger and longer-lasting settlements like Sidon as Appendix Twoly capitalizing on all available arable land and farming it, with other eco-niches viewed as barriers to be overcome or gotten rid of, these results demonstrate that the most resilient modes of settlement growth were, at least in these cases, linked indelibly to the preservation of those niches and use of their resources.

The phytolith samples collected at Sidon were started late in the excavation program, and there was not a systematic program of research designed around them. This is typical for many archaeological projects, but does mean there is some discrepancy in the distribution of the Sidon samples as opposed to those from TFK. For instance, the storage bins were not generally sampled in cross section, from base to surface, as were those at TFK; more often each bin was sampled once, although a few were sampled at different depths during regular excavation, which we will examine more closely here. In general, except for a few cases, I have chosen to present the histograms for both the real phytolith count to show differences in density, as well as the relative percentages to make the distribution more visible. Since the density is so disparate between samples, the significance of the results are most easily visible when displayed in these two ways side by side.

The density of these samples is worth a brief note here. Several of the samples from these contexts were truly incredibly dense with diagnostic multi-cell phytoliths – in absolute number counts, they were far beyond anything seen at TFK. This is likely due to the fact that these contexts were preserved with full plant content still in situ, during their use as storage compartments, whereas at TFK the settlement was de-populated and the storage compartments were likely cleaned out, then used as refuge dumps and finally abandoned when occupation of the tell became smaller-scale, as discussed in Chapters One and Two, in the EBIV. The density disparity between the two sites, then, is not taken as significant to interpreting their relational plant use; however, disparities between individual samples at Sidon itself will be discussed below.

4.3.3 Stages of Storage, Patterns of Plants

Two examples of storage compartments with multiple samples taken during excavation come from Room 4 of the mudbrick building. This room is divided by low mud brick walls into five smaller compartments, apparently dedicated largely to grain storage (**Figure 4.12**). Two of those compartments were sampled at an upper level, where charred macro-remains of grain were visible, and at a lower level near the base of the compartment. The results of these samples are shown in **Figure 4.13)**.

The first thing to note, in **Figure 4.13**, is that the presence of awn is fairly ubiquitous throughout these samples, as at TFK. This suggests that at least in this context, grain was being stored uncleaned or only partially cleaned, regardless of the type of grain. In Pit 2208, there is a significantly higher proportion of wheat than barley, whereas the opposite is true for Pit 2159, yet both have similar proportions of awn present. In these larger compartments, then, we likely have uncleaned sheaves being stored before processing.

However, when we start to look for evidence of matting or basketry, as seen at TFK, there are some interesting differences in the relationship between barley and wheat in terms of which wetland taxa are present in those respective compartments. This is a pattern that will be seen to repeat itself throughout these samples. In Pit 2208, where we see primarily wheat, there is also a high proportion of reed grass, whereas in Pit 2159 with more barley, there is a higher proportion of sedges and, to a lesser extent, cereal straw. In this case, I propose that it is more likely baskets that we are seeing, as opposed to mats or pit lining. This is suggested based on the fact that the wetland taxa in these records do not have a stronger signal from the base of the compartment, but rather from the upper level sampled, which is more consistent with a burned and collapsed basket than an underlying mat as at TFK. Furthermore, the storage compartments contained fragments of storage jars as well, suggesting that this was not strictly a granary but held containers of various sorts to be stored.

We also have multiple samples from Room 10 in the mudbrick building. From this room we have both samples from the floor itself, which seemed to be a working space, with grinding tools, broken pottery vessels, burnt faunal remains, and a possible hearth feature near piles of charred barley and wheat macro-remains. The floor was sampled at various locations where burnt botanical macro-remains were visible. Also sampled was Pit 2501, which excavators described as “below Room 10,” also containing charred wheat spilling from the floor context of Room 10 into the pit, which suggests that it was a storage area associated with the floor of that room, and likely with the work done in the rest of the room. The results from the floor of Room 10 itself can be seen in **Figure 4.14,** and the results from the storage pit beneath Room 10 are seen in **Figure 4.15.**

Taken together, these samples suggest an intriguing situation. The samples from the floor itself are presented in no particular order in **Figure 4.14**, as it is unclear from the excavation notes where exactly they were extracted from, other than generally from the various “burnt patches” on the floor around the pit. Samples 4, 5, and 6 show fairly comparable ratios of primarily wheat to trace barley, and high quantities of wild grass and sedge, and fairly small amounts of reeds, straw and *Setaria spp.* (wild millet). I suggest that the non-crop taxa here are distributed in a way that further indicates the remains of baskets or bowls. In this case, it seems likely that the wheat would be held in woven baskets or bowls while it was out in the work space, perhaps waiting to be processed. Since the burning of the building and the sealing with lime plaster left these patches of burnt organic material more or less in place, it is unlikely that these are randomly mixed remains. I suggest that these represent baskets containing wheat, and the trace barley here is overflow from surrounding contexts – such as the area represented by Sample 7. Sample 7 shows entirely barley and no wheat, with a much higher straw content and few sedges or other grass taxa. Could we be seeing a difference between the materials used for baskets and bowls to hold materials in progress (sedges, reeds, wild grasses), and mats used for material being worked on (straw)? Or perhaps a different kind of container for wheat as opposed to barley, as suggested by the Room 4 samples, as well? The high correlation of wheat to sedge is consistent with the Room 4 results; if this is a pattern, it may mean that the wheat was transferred in smaller quantities from the larger compartments in Room 4 to these smaller compartments for processing, remaining in the same kind of sedge-based containers at this stage.

This would hypothetically also be the case for barley, although we only have left the single sample here that seems to be associate primarily with straw, rather than the sedges and reeds generally seen thus far. It should be noted that the density of the barley sample is dramatically higher than any of the other samples, indicating a very densely concentrated quantity of barley present in this spot. Sample 2 may support the idea of the straw as matting on which grain could be worked, or on which the people processing the grain could sit perhaps, as this sample has no crop taxa present but is very high in cereal straw and some sedge. This sample also has such a low density of phytoliths overall that it can't be seen next to the absolute counts for the other samples, further indication of an empty/bare floor area. We might imagine, perhaps, an empty mat on the floor burned in place. There is also, of course, the possibility that the straw derives from the mud brick walls itself, as straw is frequently used as a temper in mud brick construction. The disparate densities, as well as the fact that the floor is lined with lime plaster, which is almost never mixed with straw,[15] make this scenario less likely, however, in my mind.

[15] Lime plaster is tempered with sand and occasionally, in the Roman period for instance, with horse hair, but there are no accounts that I could find of straw or plant temper used in lime plasters in the way they are used for clay/mud plasters or mud brick (Gourdin and Kingery 1975; Moropoulou et al 2000 for further discussion of early Southwest Asian plaster technologies).

In the storage pit itself, Pit 2501, the samples are primarily composed of wheat, as was the case on the floor of the room, with relatively similar distributions of wheat to straw, reeds, and sedges (**Figure 4.15**). If we accept the idea of wheat held in containers of sedge/reed, distinct from the straw/sedge surface of the barley on the floor, then we see that reinforced in these samples. For me, this strongly supports the idea of the basket holding the wheat in preparation for being de-threshed, cleaned, or ground, as it appears in both the storage pit and the floor surface of the work room. We know that at least some of the wheat was stored uncleaned, as well, based on the presence of awn (albeit in relatively small numbers), as seen in **Figure 4.16**. While awn is still present in these samples, it should be noted that it is at lower proportions overall to the awn from the Room 4 compartments (**Figure 4.16**).

The final context with multiple samples comes from just outside the mud brick building itself, in “Mud Brick Installation” 2120, which the excavators interpret as a clay-lined “storage for grains” (i.e., a granary; Sidon excavation notes). This installation was uncovered during an expansion of the College Site excavation area to create room for the construction of a new museum overhead (now open). The installation is constructed of mud brick walls with a grey clay lining along the base. The results of the phytolith samples, one from the charred grain along the back wall of the installation and one from the “clean sand” in the middle of the installation, are shown in **Figure 4.17.** These results are actually quite remarkable in comparison to the previous ones: neither sample contained any awn at all, suggesting clean grain storage at this point, and the only diagnostic phytoliths found were from wheat, reed grass (largely *Phragmites*) and *Cyperaceae* (sedges). The only difference is in density – the burnt grain patch, predictably, had a more dense phytolith content than the “clean sand,” but the proportions of the results are amazingly similar. This storage installation is built to hold its contents up above ground, as opposed to on the ground as in the Room 4 compartments, or below the floor, as in Room 10. This is a strategy still practiced for keeping grain free from rodents and insects, and makes sense as an extra protective measure as it is the only storage compartment not lined with lime plaster. In this case, then, I might suggest that the reeds are indicative of a lining or matting to protect the clean grain and seal it in the installation.

With the combination of just these few samples from different rooms in the EBII-III mudbrick building, we may be able to see the stages of grain processing activity at Sidon. I suggest that we may have grain stored in large amounts in the storehouses, such as seen in Room 4, then moved in smaller quantities to temporary storage pits in the workrooms while it awaits further cleaning or processing, and placed on mats on the floor for that work as in Room 10, then perhaps mostly cleaned but unground grain was stored ready for use either in food processing or in planting, kept in granaries like Installation 2120.

Although this study clearly needs to be confirmed with further sampling, these results already suggest that there were multiple types of storage technologies associated with different stages of grain processing in this single mud brick building from EBIII Sidon.

There are no samples indicated to have come from EBIV contexts, although, as discussed, the excavators maintain that the EBIV did not exist as a separate occupation phase at Sidon, while other researchers are strongly inclined to see a hiatus covering the EBI period at this site. We will have to await a more precise chronological record to understand which contexts, if any, at Sidon are comparable to EBIV contexts elsewhere.

4.4 A Brief Note on Wild Grasses

The reader will have noticed that although wild grasses appear in all the histograms presented, I have not discussed them thoroughly here. This is not because they are insignificant; quite the contrary. Wild grasses are in general quite challenging to identify in the phytolith record, as there are such wide local varieties and one of the morphological characteristics of wild grass husks is that they tend to be highly irregular. For the purposes of this dissertation, I have simplified and condensed them all into one category, as their further identification is still a work in progress. A quick note on some observations is warranted, however.

At both TFK and Sidon, small amounts of *Avena* spp. (oat) and *Aegilops* spp. (goat grass) were observed in the storage compartments, and although the numbers were low, they were present with a fair level of ubiquity (except of course for Installation 2120 at Sidon). Both these taxa are used in prehistoric Levantine contexts as food plants, and Aegilops in particular plays an important role in the early domestication of wheat. They are also common "weeds" that invade crop fields and can out-compete *Triticum spp.* As the sheaves of wheat and barley appear to have been brought into the sites uncleaned, it is likely these taxa came in with them as a general weed, which is why they have been grouped with other unidentified wild grasses for this study.

Another interesting aspect of wild grasses is their potential to indicate seasonality of agricultural and horticultural practices. Wild grasses seed in the Spring, and therefore their correlation in storage contexts with the domestic cereal husks may indicate that these were at least in part collected in the Spring. The correlation is indeed quite strong between wild grasses and both wheat and barley in Room 4 at Sidon, at .81 and .91 respectively (**Figure 4.18**). This may indicate not only something about seasonality, but also similar pathways via which wheat and barley were entering the site. While this correlation is only somewhat strong with either crop individually in Room 10 at Sidon, it is strong when wheat and barley are combined (**Figure 4.19**). Perhaps this is related to the fact that the crops by this stage have been displaced from their original uncleaned collection contexts, and therefore the correlation based on pathways onto the site has been obscured. Alternatively, the small sample size (only two samples per pit) makes correlation values difficult to calculate with accuracy.

It is also possible, as discussed for TFK above, that wild grasses represent fodder plants that are occurring here as part of dung residue. One future study I would like to conduct would include off-site alluvial section sampling to attempt to track the appearance of these wild grasses alongside either introduced or locally developed crop taxa and changing landscapes, to see if they might also give us some indication of preserved pastoral and foraging practices.

4.5 An Unexpected Micro-trace: An Oasis Dweller By the Sea

"Then Danel, the man of Rapau,
Cursed the clouds in the awful heat,
The rain of the clouds that falls in late summer,
The dew that drops on the grapes:

He cursed Qor-maym[16] and Mararat tagullal-banir[17]"

In this stanza from the Tale of Aqhat from Late Bronze Age Ugarit, we encounter a lesser god and earthly king, Danel, whose son (the hero Aqhat) has been killed by the goddess Anat

[16] "Source of Water," a place-name near the site of Aqhat's murder
[17] "Place of the date palm which produces many dates," another place name near the site of Aqhat's murder

because he would not be seduced by her. In a fairly typical series of lines cursing the place of the death, we find an important implication hidden in one of the toponyms: Mararat tagullal-banir, or "the place of the date palm that produces dates." By this point, there are places along the coast with notable densities of date palm, deemed significant enough in their fertility to be used as symbols of the curse of sterility in crossing the deities.

This becomes significant to our study here because within the contents of the storage compartments at both TFK and Sidon, along with distribution of known crop taxa, there was an unexpected taxon represented. This was represented by a small, but not insignificant, number of echinate spheroid phytoliths (**Figure 4.20**), which are diagnostic for palms. In the Levant, in practice, this means that they are diagnostic to the genus *Phoenix*. *Phoenix dactylifera* is the only palm species endemic to the region at the time, except for doum palm (*Hyphaene thebaica*) in the very southern Aqaba gulf area, the phytoliths of which have distinctly different morphology and dimensions (Rosen 1994). Given this, the echinate spheroid phytoliths from TFK almost certainly represent the presence of date palm that was used on site. This is the first direct evidence for date palm from Early Bronze Age archaeological contexts in Lebanon; it is also so far the *earliest* direct evidence of date palm from any archaeological context in Lebanon, and they all come from EBIII storage compartment deposits: at TFK, from Building 4, and at Sidon, from the mud brick building. This places date palm in rare quantities on the Lebanese coast around 1500 years before the lines about Danel's curse were written – by which time this had become a significant enough landscape feature to be so marked in poetry and toponym as a symbol of fertility. But in point of ecological fact, the ways in which date palm arrived and was spread throughout the coastal Levant remain largely unknown.

It is important to note at this point that I do not intend to suggest that this is the earliest occurrence of date in this area. Date palm (Phoenix dactylifera) occurs naturally throughout springs and oases of the arid regions of Southwest Asia and North Africa and is one of the oldest known cultivars of those regions. There exists clear evidence that date palm has been used for a wide variety of purposes by humans and our close relatives for millennia; for instance, by Neanderthal populations in Iraq (Henry et al 2011), and in the Southern Levant (Rosen 2003; Madella et al 2002). These areas, however, have a more hospitable natural climate for the plant and it most likely was not actively cultivated at that time. It is an emblematic oasis cultivar for arid regions, but its propagation and cultivation in the Mediterranean zones was more recent, and the pathways by which it arrived remain unclear. It was likely cultivated first in the Neolithic Arabian Peninsula (Beech 2004; Tengberg 2012) or Ubaidian Lower Mesopotamia (Gillett 1981). Even in these cases, since finds of date palm in archaeological contexts are located close to natural habitats for the species, it remains difficult to trace the precise origins of cultivation and domestication as distinct from collection (Weiss 2013). Gros-Balthazard et al (2017) suggest multiple domestication centers for date palm in the Middle East and later in Africa, although the pathways and processes of domestication are still unclear. In the Southern Levant, Jenkins et al (2011) identified date palm phytoliths from Pottery Neolithic Wadi Faynan, which they suggest could have been cultivated. We know of macrobotanical date palm remains in the Southern Levant, as well, the earliest from PPNB Ghwair 1 (Simmons and Najjar 2003), as well as later examples from Chalcolithic sites Teleilat Ghassul (Zohary and Spiegel-Roy 1975; Meadows 2005) and Nahal Mishmar (Bar-Adon 1980). Nonetheless, not enough studies have been carried out to properly understand how date entered and was adopted in prehistoric Lebanon, which has a much more varied Mediterranean, subtropical climate.

Part of the economic significance of date palm comes from the fact that nearly all the parts of the plants are used for commercially and socially valuable products. From the well-known fruit itself, to palm wine made from the sap, basketry, thatching, and matting from the fibrous trunk and fronds, and medicinal treatments derived from the roots, sap, fruit, and leaves, the date palm is processed in a number of useful and socially meaningful ways (Danin 1996; Zohary et al 2012). Its value is attested by the specific regulation of date palm orchards in the Code of Hammurabi, their appearance as attributes of the deities Ishtar/Astarte (Canaan), Dumuzi and Inanna (Sumeria), and Tammuz (Babylonia), all associated with vegetation, fertility and abundance, and it is suspected by some to be the emblematic Assyrian "Tree of Life" (**Figure 4.21**; Littleton 2005).

Nonetheless, its arrival and propagation in the area remains a question for researchers, as it was uncommon until very recently to obtain comprehensive archaeobotanical evidence that would allow its progression and use to be traced with any precision. Date palm is a difficult plant to cultivate outside of its natural eco-zones, requiring specific conditions throughout the growing period and not producing fruit until it is at least five years old. The story of its migration must therefore be understood as one of intentional, progressive human negotiations with each other and their landscapes. These results may suggest nearby cultivation, or possibly transport of palm products in one form or another from the better-known regions of date cultivation probably in Egypt, but possibly from inland Syria or further east.

The question of whether date palm was cultivated along the coast by the time of its appearance in EBA contexts at TFK and Sidon, or if palm products were transported in one form or another from the better-known regions of date cultivation in Egypt, or possibly from inland

Syria or further east, remains unresolved. It is important to note that no macrobotanical remains for date palm have yet been found at this site (Riehl pers. comm.). This means that the likelihood that the fruit was consumed in large quantities is relatively slim, as one would expect this to be represented by piths.

The density distribution for date palm phytoliths at TFK and Sidon is seen in **Figures 4.22-4.23**. The fact that the date palm phytoliths occur in every TFK Phase III (EBIII) compartment, but they do not appear at all in earlier pits could be a result of the number of samples analyzed, but the pattern is so strong as to suggest it is more significant than that. While more research is clearly needed, it is important to note that Phase III (c. 2800-2600 BCE) marks the intensification of building and settlement planning on the site, but it pre-dates the large-scale reorganization of the site in Phase IV. Phase IV may also be coincident with the realignment of Egypt's trade connections from the South Levant to nearby Byblos (Sowada 2009).

However, the palm phytoliths from Sidon all also come from the EBIII mud brick building storage contexts, indicating that it arrived in south Lebanon around the same time. If this was purely an effect of trade relationships with Egypt, we should expect to see date palm from earlier contexts at Sidon, as they were connected more closely with the Southern Levantine settlements under Egyptian control until the late fourth millennium BCE.

Also interestingly, although all the date palm finds at TFK came from EBIII storage contexts, they do not all come from the administrative complex (Building 4). Date palm phytoliths are also found in a mud-lined storage bin from Building 1, currently interpreted as a common residential structure. This suggests that access to date palm was not necessarily restricted to the administrative classes. If that interpretation is confirmed, then it implies uncommon or imported items were not necessarily restricted to a centralized authority, but perhaps distributed or accessible more widely. This could have interesting implications for understanding early trade and economic dynamics of these Early Bronze Age coastal settlements. At Sidon, so far, there is no clear way of distinguishing whether the store rooms in the mud brick building were used exclusively by the elite of the settlement or if they were more communal in nature. Further sampling as the excavation continues will help to clarify the relationships between northern and southern settlements, too – are the settlements of the Lebanese littoral really receiving new plant imports all at the same time, suggesting they are more linked as a discrete network, or at different times, showing how external trade passes through certain settlements before others? This, too, reinforces the importance of further study of ancient botanical resources and their pathways.

Although I still suggest that date palm resources were relatively uncommon on site at the time, given their absence from the macrobotanical record and fairly restricted presence in the microbotanical record, the appearance of date palm phytoliths in relatively small amounts should not be considered to be directly representative of the amount of palm used on site. Given that these phytoliths are diagnostic to species but not to a specific part of the plant itself (Rosen 1992; Piperno 2006), it is difficult to definitively interpret the particular part of palm present in this case, and therefore its use remains obscure. For reasons stated above, it was likely not the fruit itself. In general, if the palm were used for pit lining or mats, or other uses for which large amounts of the plant would have decayed together, one would expect a much higher density of phytoliths to be present. However, it is also possible that storage baskets were used, which may well have been made from palm fronds or trunk fibers, and then removed along with their contents when the storage bins were rebuilt or abandoned, as has been documented ethnographically (Danin 1996). If this were the case, then the limited quantity of phytoliths may make more sense, as the bulk of the palm product itself was removed but small fragments were left behind to decay.

At Sidon, considering the proposed role of each of the storage contexts, the date palm as baskets theory is interesting. Date palm phytoliths only appear in one context in Room 4, Pit 2159, fairly frequently in Room 10, and not at all in the Mud Brick Installation 2120 (**Figure 4.25;** there is no histogram provided for Installation 2120 since there were no palm phytoliths recovered). This would correspond with the storage areas in which baskets would be most frequently in use, and where the small number of palm phytoliths might have been left behind.

At TFK, however, if we consider the distribution, a somewhat more interesting possibility emerges. In Building 4, the administrative building with centralized storage compartments, all the palm phytoliths were found in the lowest levels of the compartments. We know from the other phytolith evidence from these pits that they almost certainly were constructed with sedge and reed matting; it seems likely that palm frond or bark would have been used as well (Damick and Rosen, in prep.). However, in the common residential structure Building 1, the date palm appears in the middle deposits of the pit, a less likely place to find discrete evidence of matting or basketry casing without also finding it lower down. To return to the broader socio-economic implications, then, perhaps we are seeing different parts of the community using distinct parts of the plant – therefore, either by access or choice, differences in palm exploitation across different parts of the settlement did not apply to the "palm" broadly, but rather to parts of the palm, or to knowledge of techniques for using it. While once again this must remain speculative at this point, it provides an intriguing first look at potential date palm pathways in and through an Early Bronze Age coastal settlement in Lebanon.

4.6 Comparison and Discussion

4.6.1 Technologies of Storage in Comparison

The construction of centralized, larger scale storage compartments and installations was clearly an important part of the infrastructural development of TFK and Sidon as they became increasingly densely aggregated over the course of the early-mid third millennium BCE. The contents of these storage compartments points to increasing specialization of agricultural production, but the construction of the compartments as well as the containers within them illustrates that this specialization could not have taken place without maintenance of wetland, and possibly pastoral, niches as well. Overall, there are many similarities in the construction of the storage compartments at Sidon and TFK, which suggests that the techniques and plant knowledge of smaller settlements are preserved in the expansion of infrastructure at larger settlements. Expanding existing techniques rather than introducing entirely new ones allows for the flexibility to always scale down, back, or return to the settlement practices from which those techniques were produced.

There are certainly differences in the construction technologies of the compartments as well. One apparent difference that stands out immediately is the presence of lime plaster evident at Sidon throughout the storehouse in Room 4, and the storage pits in Room 10 (visible, according to excavators, at a remaining thickness of 2-3 cm in some areas; Doumet-Serhal 2006). The production of lime plaster is a pyrotechnology present in Levantine settlements since at least the Neolithic (Akkermans and Schwartz 2003: 63; Rollefson and Köhler-Rollefson 1992: 243), requiring only as raw materials limestone and sand, both very available on the Levantine coast. As a coating for walls or pits, it has the advantage of being permeable, permitting the diffusion and evaporation of moisture. The elevated pH of the lime also acts as a fungicide, a desirable characteristic for long-term storage of organic material like plant foodstuffs or grains intended for replanting. However, it should be noted that there are quite a lot of fragments of lime plaster at TFK, demonstrating that they also employed the technology there, but its preservation is such that it remains difficult to tell to what degree it was used for coating walls or storage compartments. This difference may well be a function of preservation conditions, rather than actual techniques used on the sites.

A more compelling difference is one that is also difficult to compare, as we have such different storage contexts at each site. From TFK, we have a wider range of socio-economic contexts, including central storage compartments in an administrative contexts and pits in domestic residential structures. At Sidon, all the storage compartments sampled were from the central mud brick building, which seems likely to have some kind of administrative function, but from a wide range of stages in storing and processing grain. However, the difference is seen in the variety of storage structures in place at Sidon – including above ground, on the ground, and below ground, made of mud brick, stone-lined, plaster-lined, and clay-lined, as opposed to those at TFK, which seem to be largely similar in construction type, all in basements/under the house, clay-lined then reed/sedge lined. Again, it is difficult to say if this is one of the functional differences of scale. Perhaps Sidon, as a larger, more centrally administrative settlement in the coastal Levantine network, consolidated crops from surrounding areas for processing and redistribution or local use, much in the way we might imagine Byblos would have done for the northern settlement networks. In such a case, a smaller settlement like TFK would only need to keep enough grain for its own lower population, re-planting, and would pass the rest of the uncleaned product on to Byblos. However, without access to greater exposure at both sites, this remains a preliminary model.

The practice of lining storage containers with straw or sedge to keep grain dry and trap in natural gas release is known from nearby Tell Arqa (Thalmann 2010), as well as a number of other prehistoric sites in the region (Engel 1996; Pfälzner 2002; Milevski et al 2016). As Jane Renfrew (1973) pointed out many years ago, grain will more often be stored in this careful way when intended for long-term storage, as slightly moldy grains can be eaten if necessary but they can't be planted. The method of sealing in grain to protect it from insects and contain CO2 gas release is described by ancient agronomists such as Aristotle, Pliny, and Columella (Panagiotakopulu and Buckland, 1991; Gast and Sigaut 1979; Shejbal 1980; Thalmann 2010). Once the sealed compartments are opened, the grain must be used quite quickly or it will begin to mold at an accelerated rate; this is therefore a good method for storing grain intended to be planted once the bin is opened, but not for grain intended to be apportioned out gradually. This may explain why there is more clear evidence for sedge/reed sealing in some compartments but not all of them, as well as the different sizes of storage at Sidon. We likely have at least some of this storage intended for the next planting season, and not just for redistribution or export along trade routes. It also makes sense that small portions of grain would be stored at a time to be processed, as those would be frequently accessed, and they would not have wanted to reopen large quantities intended to be planted the following year.

At Tell Arqa, similar techniques were observed for the later EB periods (Stratum 16-15, or the early-late EBIV, the second half of the third millennium BCE). Until now, this is certainly the most extensive evidence for the diversity of storage techniques in EBA Lebanon and their increasing significance to complex aggregated settlements. Jean-Paul Thalmann, the project director, describes the late EB households destroyed, also, by conflagration: "[…] the most characteristic and new feature is that each house had its own granary: all rooms at ground or basement level were partitioned into small "cells" by thin mudbrick walls and were used only for storage […] Excavators retrieved large quantities of charred cereals stored in pottery jars or sacks and basketry containers or as bulk storage in the individual cells. Many partition walls were found still standing to a height of 1.5-2 m, showing that most of the cells could be entered only from the top, through access holes in the floor of the upper story" (Thalmann 2010: 92; **Figure 4.24**). This is remarkably similar to the situation at Sidon, in terms of the partition of storage rooms into cells by the construction of mudbrick walls. It is similar to TFK in the sense that all the compartments were found in the basements or below houses, and accessed from above. In fact, Thalmann describes the way in which all available ground space was transformed into storage space by the blocking off of doors and dead end street space, ending up with a situation by the late third millennium BCE where all living was conducted on upper stories (Ibid).

Perhaps most importantly for our purposes is the evidence attesting various technologies directed towards long, middle and short-range storage at Tell Arqa. In the mud brick storage cells, excavators recorded a thick burned layer of "mixed hacked straw and husk above and under the bulk of charred cereals, also sticking to the walls of the cells" (Thalmann 2007; Thalmann 2010: 93). It is probably, I believe, that further phytolith analysis of this lining would reveal sedge and reed, as well as straw and husk. Therefore here we also have cells specifically for long-term grain storage, but divided into smaller compartments to allow some of it to be unsealed when needed without jeopardizing the entire crop. Storage jars, as well as baskets or bowls, were used for middle or short-term storage, as seen at Sidon and TFK.

Examples can be found in the surrounding regions as well. One comparative example, albeit larger-scale, can be seen at Ebla, from a silo south of Palace G. The excavators note that the interior of the silo was also plastered, as at Sidon, and that there was a small amount of weedy wild grasses and chaff recovered alongside the grain, suggesting to them it was used for storing partially-cleaned grain (Wachter-Sarkady 2013: 377–378). As discussed further below, smaller-scale storage of clean grain was located in the palace itself. This again reinforces the idea that stages of processing and cleaning coincided with the movement of crops through different storage environments, attended by different technologies; at Ebla, no mention is made of the use of wetland taxa, which may be a difference related to the semi-arid environment of that site. Khirbet ez-Zeraqon in northern Jordan is another example of a "palace," or at least a large central building that emerges in the EBII-III, and wherein storage compartments and economic activities are found in close proximity in one area of the building, separate from administrative activities, and probably only serving the needs of the palace itself whereas communal storage must have been located elsewhere (Genz 2002, 2003).

4.6.2 Capacity and Economics

Although it is not the primary interest of this dissertation, it is impossible to discuss storage compartments without thinking about their potential capacity and its economic function;

it is, after all, based on assumptions about capacity that we often base interpretations of household, community, and surplus storage economic relationships. Choices that local populations make about growing different plants, expanding and contracting agricultural or pastoral space, and conserving different resources can only be modeled based on some interpretation of how much of those resources could be stored, and over what length of time.

Accurately assessing, or even just reasonably estimating, the actual size of storage compartments during their use lives, let alone their storage volume, capacity, and how many people fed that that translates into, has been a thorn in the side of archaeologists for decades. There are nearly as many methods for converting storage volume (cubic meters) into stored product (kg of grain, most frequently) as there are reports on storage facilities, especially for regions like Mesopotamia where models for early settlement aggregation are hinged on the role of surplus grain agriculture (see, for example, Paulette 2015: 46; Schwartz 1994b: Table 2; Danti 2000: 129; Seeher 2000: 293: Note 105; Gallant 1991: 96-97). Tate Paulette has recently attempted to standardize models for barley storage capacity in Early Bronze Age Mesopotamia using computer modeling of silos (Paulette 2015, 2016). However, he comes to the conclusion that there are such a wide variety of conversion factors available, and those factors change the output values so dramatically, that any estimate must still be interpreted with a healthy dose of intuition and critical evaluation (Ibid).

If I use Paulette's standard conversions,[18] the largest compartments at TFK, in Room 5 of Building 4, are approximately 1.5 wide by 1.5 meters long and .75 meters deep, giving them a

[18] Paulette's minimum (1 m3 = 444.4 kg barley) and maximum (1 m3 = 934.6 kg barley) values for converting storage volume to threshed barley are drawn from Hole (1991: 24) and Reynolds (1974), respectively. He also draws on Schwartz 1994b: Table 2 for nutrient requirements of stored grain.

storage volume of almost 1.7 cubic meters. This converts to 755.48 kg (.758 tons) of grain if the product were stored just as clean grain – however, in uncleaned sheaves, this quantity would clearly be less, possibly quite a lot less. If we imagined all three Room 5 storage compartments simultaneously full at a maximum capacity of .755.5 tons of clean grain each, for a total of 2,266.4 kg (2.26 tons), it is impractical to convert that into people fed, as clearly portions of that grain would be stored for future planting. It is very clear that other storage facilities must have also existed at TFK, given comparison with Arqa and Sidon, and have not been uncovered by the excavations. At Sidon, the storage compartment "cells" in Room 4 are somewhat bigger, at 4 cubic meters or 1777.6 kg (1.78 tons) of clean grain capacity each. This makes the total capacity of the Sidon storage facility many times greater than that at TFK. However, this still only compares to the most modest of storage facilities in Greater Syria – for instance, the rectilinear silos at Tell Hajji Ibrahim, which have been calculated to each hold a volume *per vertical foot* of 2.64 cubic meters, or 1320 kg of grain, enough to feed 6.6 people for one year (Danti 2000: 131; Paulette 2013: 107).

This simple calculation is not only difficult to operationalize due to lack of complete storage area exposure on these sites, but also because it of course leaves out all of the actual critical variables to the cycles of people interacting with plants – the fact that people ate quite a lot of other things besides bread or porridge, including a variety of grazing animals whose fodder should be accounted for, the fact that it clearly wasn't clean grain stored in these compartments, it probably wasn't all for consumption, and likely the compartments were not all at full capacity at a given time. Moreover, different people of different ages, genders, social status, and health will eat differently. This of course raises the problem of distinguishing between what people biologically need to eat to stay alive, and what they need and/or want to eat to undertake different daily tasks, deal with different medical issues, and participate in different social and cultural practices. We can already tell that the faunal consumption patterns at Sidon were very different from those at TFK, with the former relying more heavily on wild, hunted game, and the latter on domesticates, largely ovi-caprids. The precise nature of the daily diet is still being explored for EBA Lebanon, and therefore any calculations of storage capacity such as those introduced here must be very cautiously applied.

Given the data we do have, I believe we have to consider that at TFK, Building 4 was specifically intended for the storage of crops for use by the administrative households or elite of the settlement center, including grain preserved for re-planting for those households, and that storage for the community or for trade was located elsewhere. While we may take these as a model for technologies of storage being used on site, and compare them with regional analogues at different scales, we do not have a complete picture of storage facilities at TFK. The clear administrative link of TFK to Byblos suggests that much of the local crop product would be transferred on to that settlement, so storage within the central building structures of the site likely was only intended to supply those residents, whereas storage for the general population and intra-regional trade would be located elsewhere. We might think, for instance, of the situation seen at Ebla, where the storerooms attached to the central EBA palace are not, in fact, sufficiently large to account for the quantities of grain needed to sustain Ebla's population; that is interpreted to have been kept in peripheral buildings at the edge of the settlement (Dolce 1988: 41; Marchetti and Nigro 1996). Mazzoni further proposes that the Royal Palace G was "the seat of accumulation and redistribution" for the Ebla state, but only in a theoretical and administrative sense, rather than in material reality. The goods stored within the palace itself would have been intended primarily for internal use, and the storerooms there would be symbolic of agricultural plenty and settlement provision. “The storehouses that lay at the center of the redistributive economy should be sought elsewhere in the city or, perhaps, outside of the city” (Mazzoni 1988: 92).

This may well also be the case for Sidon. Although the mudbrick building there is much larger-scale in terms of storage capacity, the settlement itself was significantly larger too, making this a question of comparable proportions. Sidon in fact is probably, at a local scale for Lebanon, more comparable than TFK to the palatial economy seen at Ebla, and the mud brick building replicates the rooms for working as well as storage seen in Ebla’s Palace G, or at Khirbet es-Ziraqon, and likely Byblos. In this way, these sites seem to consolidate labor, as well as resources, from surrounding smaller settlements into a central administrative complex that serves as a visual metaphor for the way in which the settlement at large brings together larger-scale resources and labor to provide for the community and in some cases, engage with trade.

Nonetheless, without evidence for a much larger storage capacity at either site, it is difficult to imagine that they were involved in very widespread, large-scale interregional trade economies based on their grain production. For coastal Lebanon, I see storage as part of local, small-scale but hierarchical redistributive institutions, but as much more invested in maintaining foraging and pastoral opportunities should those institutions need to shift or be relocated. On-site storage is part of a negotiation between intensification efforts and conservative strategies of resilience. Given the restricted arable land space of the Lebanese coast, there is no way the EBA Lebanese settlements could compete with the territorial expansion or massive quantities of grain produced in Syria, Mesopotamia or Egypt. Indeed, in discussing the evidence for olive oil trade in the Levant, Genz has argued for a local, intraregional Levantine network for the production and movement of staple crops, based on the staple finance model for complex agrarian societies described by D'Altroy and Earle (1985:187-88; see also Philip 2001).[19] In this model, subsistence goods are collected by the administrators of local, small-scale socio-economic and socio-political institutions, and redistributed to those working for those institutions; however, critically, most workers are only committed part-time to these institutions and continue to practice some degree of subsistence provision themselves.

Genz describes the situation for the EBA Southern Levant: "Moving from EBA community to community, the scale of storage facilities may vary, but in all cases there is ample evidence to demonstrate the collection and storage of goods by non-residential institutions, often labelled palaces by their excavators" (Genz 2003: 72). The micro-botanical evidence presented here supports that model, while offering a more complex picture of the stages of storage that accompanied local accumulation and processing by these central institutions. This new evidence also introduces that degree to which local wetland niches had to be maintained in balance with staple crop agricultural zones, which certainly must have effected the scalar development of local institutions.

4.6.3 Stable Fixtures, Mobile Landscapes

It is also important to remember that at the end of the day, storage capacity is less important than the role of the storage installations to mobilize different plant resources through the landscape; this is its role as material infrastructure, conductor of labor, materials and

[19] Although the case for wine may be different; see Chapter Two.

relationships that allowed settlements to expand or contract as needed, and reinforced social and economic relationships through use and maintenance. How much grain was coming in and being taken out, as well as how much of the sedges and reeds were brought in and out to preserve it, and all the attendant practices of producing and curating the landscape niches from which those plant products derived says more about the strategies and scale of EBA settlements than the size of storage compartments alone does. And in this sense, we may see the movement of plant resources in and out of the central administrative complexes – the households at the core of the governing institutions – as models for the movement of such resources in relation to the landscape at the larger settlement scale. This concept is explored more thoroughly, in relation to concepts for Canaanite just leadership in relation to the environment, in Chapter Six.

Chapter Five

Storing Technique, Skill, and Mobility: the Ground Stone Use Wear Pilot Study

"With a knife she split him

With a fan she winnowed him,

With fire she burned him,

With millstones she ground him,

With a sieve she sifted him,

in the field she sowed him,

in the sea she sowed him."

- Anat, Ugaritic Baal Cycle, Tablet 6, Column 2 (Coogan and Smith 2012: 148)

5.1 Ground Stone in Text and Analysis

In the text above, Anat takes the death god Mot through all the stages of the harvesting cycle in order to bring about the resurrection of her brother Baal and the return of the rains to the fields of Canaan. In doing so, she acts not as his sister, lover, or royal warrior and protector (all roles she adopts at different points), but as his mother: "as a cow to a calf" (Ibid). In taking up the tools of harvest and processing, Anat invokes the relationship of care that travels from one generation to the next, and the skill and knowledge that such relationships transfer over time that sustains the balance of the seasons and the life cycles of the land. Grinding tools speak to this kind of carrying-down of skilled knowledge in a unique way, as they have far longer use-lives than most other artifacts of daily lives, and are documented to have traveled as inheritance in many societies (Wright 1994; Adams 2014; see discussion below). This chapter attempts to bridge the concept of the multi-generational tool with the empirical evidence from the first pilot study of ground stone tool use wear in Lebanon, to explore how these tools stored within them both functional and symbolic possibilities as they were transported through time and space.

Ground stone tools have been collected since the earliest archaeological investigations, and have (like storage pits) stood at the center of many archaeological interpretations of the development of agriculture and increasing sedentism leading up to the Neolithic. Nonetheless, we still have very few well developed methods for ground stone analysis. It is only in the past few decades that use-wear analyses have begun to disassemble previously held assumptions about the way grinding tools functioned in ancient societies – most notably that they were not all, in fact, used to grind grain (Dubreuil et al 2016; Adams 2014).

Use–wear analysis can provide information about the way a tool was used, while residue analysis can identify the processed material to a greater degree of precision. Kinetics refers to the repetitive motions the human body undertook in using the tools, which generated repetitive friction on the tools with a certain set of characteristics – directionality, speed, intensity, frequency, etc. While form clearly does not necessarily equal function, it does constrain the range of ways in which the tool can be employed, as it informs and retains traces of the kinetics of use (Horsfall 1987; Sigaut 1991; Plisson 2006). Functional variability on the same tool has been observed, for instance, on handstone-like tools used without a lower grinding slab to process hide, which Adams calls “lapstones” (Adams 1988, pers. comm.; Dubreuil and Grosman 2009). Use–wear is a particularly useful approach to unravel the way a tool was used, as it allows the analyst to observe the different working surfaces of the tools, the manner of prehension or handling, and the direction of the motion (Dubreuil et al 2016).

There is of course more to fully understanding the function of a tool than reconstructing the kinetics and mechanics of processing. While the range of matter processed and the kinetics involved are important parts of the picture, researchers increasingly urge a holistic approach to ground stone tool analysis. Sigaut's (1991) methods, for instance, specifically include questions about who used the tool (a specialist, different family members, children or women or old men), for what purpose (i.e., family meals, local craft production, a large party), and when (not just 5,000 years ago, but whether it was frequently, occasionally, or rarely). While we should keep this perspective in mind, this is not only currently beyond the scope of this project, however, but it remains beyond the scope of our analytical methods in most cases (Dubreuil and Savage 2015).

Nonetheless, we can design studies around tools that limit the range of functional possibilities and develop strong multi-proxy approaches within tools from particular archaeological contexts to start to expand the scope of the analytical methods that are available. For instance, ethnographic studies indicate that tools associated with graves may represent a range purposes, such as personal possessions, gifts, debt payments, offerings, or funerary rituals (e.g., Ucko 1969; Binford 1971; Carr 1995). At the Natufian site of Hilazon, various types of ground stone tools were found associated with burials, including a small abrader with wear patterns similar to those observed on pebbles used as pottery burnishers (Dubreuil and Grosman 2013). While pottery production is not in evidence until a much later period in the region, the burial pit in which the abrader was found was plastered with clay, suggesting the possibility that this abrader was used in the preparation of the burial pit into which it was later interred (Ibid).

The good old-fashioned use of a defined and discrete archaeological context, then, can provide crucial data alongside use wear analysis for understanding the function, context of use, discard behavior, and symbolic aspects of the ground stone implements (e.g., Lidström Holmberg 1998, 2004; Tsoraki 2007; Wright 2008, 2014; Roda Gilabert et al. 2012; Buonasera 2013; Delgado-Raack 2013).

The critical role of use wear for the work of this dissertation is its potential to allow the analyst to assess the possible ranges of materials processed and techniques of use corresponding not just to the last stage of tool use, but of earlier stages as well. Identifying these phases and reconstructing the history of each tool is an important step contributing to our understanding of the broader artifact function, and therefore of how it relates to larger issues of landscape and resource use, and the ways in which technical knowledge and possibility are kept present in different tool types. It is therefore critical to establish the "sequence of wear" (established by Semenov 1964; Risch 2008) through experimental and comparative study.

In this chapter, I will first present the macro-level assemblage description for each site, focusing exclusively in this case on context and patterns seen among tools for grinding, pounding and abrading (grinding slabs, handstones, abraders, pestles, and pounders). For the purposes of this study, other ground stone objects like the perforated stones (mostly weights and beads, see Damick in Genz et al 2016) and grooved stones (digging mauls and a small weight) are excluded. Next, I will describe the preliminary results from the pilot use wear study and discuss the ways in which they point to future directions for understanding technological storage at TFK and Sidon. Finally, I will present a brief description of the raw material range of the tools analyzed and what that might add to our understanding of their role in the landscapes of EBA Leabnon.

Many studies of late prehistoric grinding tools emphasize the fact that these tools can be quite large and heavy, and therefore constrain the possibilities for their use by mobile communities (however, see: Boyd 2006; Maher 2010). At TFK and Sidon, I find a pattern of reuse of fragmented and broken objects – sometimes intentionally broken – that suggests that the ability to move these tools and activate particular kinds of processing work whether or not the user is at the settlement itself or not, indicates a different strategy behind tool use at these settlements. Whereas large centralized sites like Ebla and Megiddo have revealed large rooms dedicated specifically to large-scale grain processing on large, specialized grinding slabs (**Figure 5.1**), the same are not in evidence at EBA sites in Lebanon so far. Instead, we see small-scale toolkits that are consistent with household economic behavior as well as with both sedentary and mobile lifestyles. By this I mean that these "toolkits" contained a range of large and fragmented tools that were designed to be used as paired tools (one stationary, one mobile) or reused as individual or paired mobile tools after breakage. This is a strategy that I suggest corresponds with the evidence in Chapters Three and Four for diversified plant use strategies, including the continued processing of wheat after the settlement is no longer occupied on a large scale.

5.2 The Assemblages

Ground stone has been collected since the earliest archaeological work at Tell Fadous-Kfarabida, but only became systematically integrated into collection strategies and analysis in 2009. From the 2007-2011 excavations, 409 ground stone tools have been recovered from the site, including milling stones and handstones, mortars, pounders and pestles, abraders and polishing pebbles, stone weights (probably for fishing nets), mauls, and grooved stones; this count excludes decorative worked stones, such as beads, pendants, and geometrically incised pebbles (Damick in Genz et al 2009; Damick in Genz et al 2010). From this assemblage, this section primarily analyzes a subset of 214 grinding tools and tool fragments, including milling stones, handstones, mortars, and crushing/pounding tools (pestle/pounders), and a subset of 97 perforated stones, although reference is made to other parts of the assemblage where relevant. This selection has been made for this analysis as for two reasons: first, because these objects seem to occur more frequently in association with residential and public buildings, in some cases possibly as toolkits; and secondly, because they represent a set of tools with readily comparable manufacture, material, and consumption (whereas it is not clear so far that many of the other object types were part of the same production and consumption networks).

As with the phytoliths, there was never a protocol for the systematic identification and collection of ground stone at Sidon. As discussed above and in Chapter Two, this is not unusual, but it does mean that the comparability between the two sites must be taken with a critical eye to the effect of differential collection rates. Limestone and coastal sandstone tools, in particular, are difficult to identify to the untrained eye, and so are likely significantly underrepresented at Sidon, and at any site without a specialist present for at least part of the excavation process. In some cases, beach pebbles that have been identified as ad hoc tools under the microscope show little evidence of use at the macro-scale even to specialists; this is why complete collection protocols until the range of local tool types can be identified is advocated for the future.

Another important point to note when considering this data is that ground stone tools are notoriously more difficult to precisely date than most other artifact types, because they can have a long, multi-generational use life, and are more durable than most other artifacts of daily life, and are quite frequently reused as fill, architecture, decorative, or burial objects after (sometimes long after) their time of production and primary use. Therefore, I have not attempted for this analysis to break down a chronological range within the EBA for raw material procurement. All the tools studied here were used during the EBA, but many show signs of reuse and re-shaping. As we are attempting to understand use of different geological resources (and therefore think about zones of access in the landscape), rather than just use of tools over time (this is examined in Chapter Five), it would be misleading to break down the chronology with any more precision at this point. Instead, raw materials are presented as they occur across different tool types and whether they represent ad hoc, planned manufacture, re-use, multiple reuse, or exhaustion patterns. This will give us an idea of which raw materials generally were privileged, which were curated, and how those were stored across the EBA broadly. Chapter Five will break down preliminary use wear studies of a selection of the tools and attempt to better articulate patterns of storing and reusing techniques and possibilities for processing practices in relation to settlement patterns.

5.2.1 TFK Assemblage

Preliminary analyses of the TFK grinding stone assemblage has been published elsewhere, and this repeats some of those findings (Damick in Genz et al 2009, 2010, 2011, 2016). As described above, establishing the contexts of grinding stone use is a necessary consideration before attempting to assess their function through other techniques. Of the 214 tools analyzed for this dissertation, only about 80 come from apparent living surfaces across all occupation phases and buildings; however, almost half of the remaining artifacts come from a range of other "use" contexts, including reuse as architectural features (mortars as column bases, slabs as wall stones), and storage in pits, leaving around 180 tools and fragments from midden contexts, room and street fills indicating "final," discard.

The majority of the ground stone objects across all occupation phases were broken (although not necessarily exhausted), and recovered from fill levels between and below floors, in streets, and above occupation levels (i.e., after abandonment). These represent secondary depositions as refuse and/or to bulk up architectural fill levels, and this is not unusual for settlements occupied throughout the later prehistory of the region. It can reasonably be imagined that most tools that were both portable and still functional were taken with the site inhabitants when they left the settlement. There is evidence from Mesopotamian Bronze Age texts, at least, that grinding stones were considered valuable personal property, often linked to female inheritance (Wright 2014: 26). Even without extrapolating the values from these texts onto Levantine societies, we can imagine that any still functioning grinding tools, especially those made from more difficult to obtain materials, would have been worth taking along when houses were left behind. I have suggested elsewhere that the raw material distribution dominated by coastal materials, which were easily replaceable, and only reused basalt fragments, is due to people taking more valuable tools with them upon settlement dispersal (Damick in Genz et al 2016). Here, however, I'd like to consider a different possibility (one that does not rely on negative evidence): I suggest that fragmentation is key to understanding the strategy behind ground stone use at the site, and may not be an accident of representation and depositional factors.

There were some instances in which floor surfaces were not entirely cleared of in-situ material before they fell into disuse, and in these cases, grinding tools are a frequent part of the floor assemblage. As has been described elsewhere (Damick in Genz et al 2010), a small but diverse range of processing tools were recovered from Building 1 across several floor levels of Phase III. In Room 1, each floor surface contained one broken limestone milling stone, often along with several pieces of broken hand stones. Two basalt hand stones were carefully curated; one was discovered inside a cooking pot and the other in a storage bin. By contrast, in Room 2, three stationary grinding slabs and four basalt hand stones (two partially reused) all came from either directly on or just above the lowest exposed floor level. A polishing pebble, pumice stone, two limestone lids, and a small basalt grooved stone from contexts associated with the same living surface are further evidence of the high proportion of fine and valuable stone products in use in that space. If we take these floor assemblages seriously, then the frequency of reused and reusable fragments is a strong pattern not isolated to contexts of discard, and not isolated to domestic work contexts as opposed to those with evidence for more specialized and perhaps elite work (**Figure 5.2**). I suggest that this tells us that we should consider the distribution of use across material and tool types with a more critical eye.

Another strong line of evidence supporting this comes from the mortars. First, all mortars are limestone or sandstone; there is no evidence for the use of basalt mortars on this site. All of the “miniature mortars” – a term used for the basal unit of a set of pounding tools measuring under 10 cm in diameter, which clearly must be produced for some specialized purpose, as they are not useful for general processing – came from mid to late Early Bronze Age III contexts (**Figure 5.3**). This coincides with a general tendency towards increased specialization on site, seen also in the faunal and botanical data (including the date palm described in Chapter Four). It is possible that in fact some of these smaller mortars served as capstones for drilling – as drilling technology is clearly evidenced on site during this phase, as noted above (and suggested by Wright for similar objects in the Neolithic: Wright 2008: 138). Use wear analysis of these objects is complicated by their material composition, however, as the grains are extremely loose and friable, and those that might retain micro-evidence of wear could not be detected in this pilot study, and in fact have almost certainly fallen out at some point over the past five thousand years. However, the instance of one such object with a small hole drilled in the side, presumably so that it could be suspended from a string or leather strap and carried around, may suggest that these were personal craft tools (**Figure 5.4**). Given the late appearance of miniature mortars and the comparatively fine quality and diversity of stone objects found across Phase IV floors (including whetstones, pumice stones, stone beads, and fine abraders), a picture emerges of increased technical complexity, and by extension craftsmanship, of stone material culture on site after Phase III. At the other end of the spectrum, the large, stationary boulder mortars embedded in floor surfaces only appear in likely semi-public or shared spaces (**Figure 5.5**). For the earlier Phase III, there is a large mortar embedded in the floor of Building 1, Room 2, the only room to have access at street level, and so far interpreted as a possible public meeting space. In the later phases, there is another such mortar in Building 4, in the suite of rooms that is seemingly assigned to food preparation for the administrative complex.

Belfer-Cohen and Hovers (2004) also draw attention to the role of labor and energy expenditure that grinding tools signify. They point out that large, deep mortars required quite a lot more energy investment to manufacture than did small grinding slabs or querns, for which reason they suggest that Natufian communities only went to the trouble of producing such mortars if more than one family were to use them. Although we are considering a very different time and situation at Tell Fadous-Kfarabida, we do see (as described above) that the large boulder mortars embedded in floor surfaces primarily occur in rooms that seem to have at least a semi-public function. These mortars required the most energy investment to produce, but they also have the largest use surfaces themselves and thus could produce the largest quantity of processed material at a time; in fact, wide-lipped mortars such as those seen at TFK have been proposed to be multi-functional tools, where pounding took place in the mortar base and grinding on the flat lip surface, which would allow more than one person to work with them at once (Adams 2006). There is a suggestion, then, that the public nature of rooms in Area II – beginning even from Phase III – can be traced through the ground stone processing tools, as well.

Experimental research in food processing from the southern Levant has already shown ties between ground stone technology and efficient plant resource management. For instance, Wright observes that fine processing of vegetal material allows for the extraction of maximum nutritional value from a smaller quantity of grain, by exposing a larger proportion of the surface of the grain, allowing a larger population to live off a smaller resource base (Wright 1994). If we accept the suggestion that the preponderance of open grinding slabs among the milling stones (as opposed to querns, basin slabs, etc.) indicates a focus on such fine grinding (see use wear section below for further supporting evidence), probably of cereals, then we are presented with more evidence to support the interpretation of Tell Fadous-Kfarabida as primarily a center for administering surplus products under the control of a somewhat larger settlement like Byblos. Although the macrobotanical evidence clearly shows a surplus production of wheat at Tell

Fadous-Kfarabida, it seems that the site inhabitants were not processing it on a large scale and had toolkits designed to make the most efficient use of small amounts of grain; this also corresponds well with the phytolith data from on-site storage. If large quantities of the uncleaned cereal crops were exported to Byblos for systematic and centralized processing like that suggested at Sidon (Chapter Four), then the grinding assemblages evidenced at TFK are those representing the strategies of local populations for their own processing needs.

Overall, the ground stone assemblage at Tell Fadous-Kfarabida supports the interpretation that the settlement was a small but significant specialized center occupying a likely second-tier position within a complex, locally hierarchical network of economic access and control. The processing tools resemble those of a small-scale, household-based production, lending credence to the suggestion that the overall population living at this site may not have been very large, or that the entire population did not live full time at the settlement, but rather moved between the settlement and the larger agricultural and pastoral zones of the coast and foothills. The extensive curation of basalt tools, including evidence for intentional breakage before tool exhaustion, followed by reuse, indicates two things: a) that this was a valuable material to which inhabitants did not have unrestricted access, and b) that portability and reuse of smaller versions of the original basalt tool were valuable parts of tool kits. I suggest that point (b) supports the existing evidence for a cyclical strategy of landscape use that depended on parts of the population accessing and managing different eco-zones at different times. Toolkits were needed that were useful within the settlement itself and also that could be transported, at least in part, when people dispersed from the centralized settlement area to manage woodland or wetland resources from the foothills, for instance.

However, the appearance of increasingly well-made and diversified ground stone tools in the latter part of Phase IV – particularly those that may be associated with specialized craft industries, such as the miniature mortars/capstones – suggests that, at least for certain purposes, the settlement did have access to broader technological networks. More research is clearly needed in order to better understand the full implications of this assemblage, and the specific technologies through which the settlement functioned as a specialized center within the regional network of Early Bronze Age complex, densely aggregated sites.[20]

The use wear evidence described in Section 5.3 below demonstrates that questions of technical specialization and categories of tool reuse can be accessed in this assemblage, even though it is primarily made of coastal limestone. Microscopic use wear patterns show a range of identifiable possible material categories being processed, and that different use categories develop in distinct ways according to tool types and which tools are reused. The evidence from this pilot study largely supports my suggestion that the fragmented tools should be considered more seriously as a tool category themselves, rather than as remnants left behind, and that they hold within them the potential for cyclical relationships between settlement expansion and contraction in relation to the landscape that is seen in the phytolith evidence of Chapters Two and Three.

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[20] Research elsewhere in the Levant has shown that the development of ground stone procurement is linked to the development and organization of other production and exchange systems (see, for instance, discussion of the links between copper smelting and bead making in Wadi Faynan in the Early Bronze Age I: Adams 2002). The miniature mortars at Tell Fadous-Kfarabida, given their appearance in the latter half of Phase IV alongside other evidence for drilling and most of the stone and shell beads, might indicate that these tools index a similar kind of technological specialization, if on a much smaller scale. As this is not the focus of this dissertation, it is not expanded upon further here, but provides a fruitful avenue for other kinds of ground stone study.

5.2.2 The Sidon Assemblage

Grinding slabs (complete and broken) are by far the most numerous tool type of the grinding tool assemblage from EBA Sidon; of the 123 tools analyzed, 78 are grinding slabs (the lower, typically stationary stone of a paired two-stone grinding kit). 65 grinding slabs are basalt and 13 are limestone. 19 handstones are attested, 4 of which are limestone and 15 of which are basalt. The remaining tools include seven limestone miniature mortars, three small abraders, one limestone disk (likely a lid; see Damick in Genz et al 2009) and a collection of basalt fragments. Several large limestone mortars (i.e., 1270, 2506) that were found set into floor surfaces were unavailable for direct analysis. If it is accurately described by the excavation notes, it is worth mentioning as it is further evidence of the parallelism between mortar technologies at TFK and Sidon despite the differences in the rest of the assemblage; however, a tool similarly described as a large mortar in the notes was in fact found to be a trough (or basin) grinding slab upon direct observation, so this should be taken critically.

As described for the phytoliths, clear phasing of the contexts at Sidon is more challenging at TFK, so the emergence of specific tool types chronologically cannot be attempted in the same way. Again almost all tools come from the EBA mud brick building in the central part of the ancient tell, known as the College Site Excavations, and a smaller quantity are from areas just outside and surrounding the mud brick building, uncovered more recently during the Sidon Museum Expansion excavations. The stratigraphy of the EBA mud brick building is variable from room to room, of course, but largely seems to show cycling episodes of occupation/use surfaces, burning/collapse, re-levelling and re-occupation/use. Most of the grinding tools come from collapse and fill episodes. I tentatively suggest that despite this, and even with the reservations surrounding the collection bias described in Chapter Two, we cautiously take the distribution seriously as we have for TFK to draw out useful patterns for contextualizing the use wear results.

There are a few contexts that may be useful in this regard. There is, for instance, in Room 6 of the mudbrick building a context described as a pile of stones on a floor, "consisting of roughly square stones 44x22x17 with flat tops and smaller stones with a flat top and cruder stones with no facing against south of wall 2470" (Sidon excavation notes). Only one stone from this group was kept as an artifact, and is a reused basalt hand stone. It is possible that this represents a pile of stones intended for use architecturally or in fills (and the hand stone was intended to be used in this regard as well). However, this also sounds suspiciously like a pile of stone blanks in stages of preparation for modification as stone tools. If that were the case, we would have the first direct evidence of ground stone manufacture in Lebanon, but unfortunately it must remain speculative for now.

Even in floor assemblages from the mud brick building, there are no large-scale, specialized grinding slabs of the kind seen at Ebla, for instance. In the case of any floor that contained processing equipment, such as floors 2057 and floor 2187, that equipment consisted of one large mortar and a few smaller grinding tools. For floor 2187, for instance, these were a broken slab and a complete handstone, both basalt. For floor 2057, two grinding slabs were recovered and no hand stones. In this latter case, these stones appear to have been recovered from a hearth context, which may indicate their use in toasting or cooking activities as well as grinding activity (**Figure 5.6;** Adnan Baysal, for instance, has proposed the identification of similar objects as cooking slabs in Neolithic Anatolia: Baysal and Wright 1995, Baysal pers.

comm.). This is much more similar to the household-type toolkits seen at TFK than it is to the specialized industries at the large palatial centers in Greater Mesopotamia, or even the larger centers of the Southern Levant.

Occasionally, grinding tools turn up in unusual or “special” contexts from EBA Sidon that are not seen at TFK. These are shallow pit deposits, not described in Chapter Four as they are clearly not intended for the storage of agricultural products, but for the placement of special deposits. Such shallow single-deposit pits often include dense deposits of only astragali (caprid knucklebones), or only dense shell deposits, sometimes with multiple jars whose contents remain so far unknown; these have been proposed to be symbolic deposits (Doumet-Serhal pers. comm.; Sidon excavation notes). In a few cases, grinding tool have also been recovered from these contexts. This is the case for contexts 1045 and 1271; in the former case, a broken basalt grinding slab was included, whereas a reused basalt fragment was included in the latter.

The inclusion of these tools in (tentatively) symbolic pit deposits emphasizes the point I propose here, that we should consider fragments as significant alongside other tool types, as objects that still held within them the possibility for other uses and perhaps even symbolic importance tied to their role in carrying technical knowledge and the possibility for its use throughout generations. It also opens up a new context for exploring the role of grinding tools in storing meaning, as well as technological possibility, over time. This kind of symbolic storage in grinding tools has been explored for the grinding tools deposited in burial contexts from earlier periods in the Levant, such as at the Natufian Hilazon (Dubreuil and Grosman 2009), Mallaha (Boyd 1995); and Pre-Pottery Neolithic Horvat Galil (Gopher 1998) (see also Belfer-Cohen 1991; Rosenberg 2013). As more information becomes available from the Sidon special deposits, and hopefully from other sites in Lebanon, this should provide the basis for thinking about how such uniquely robust, multi-generational tools act to preserve symbolic and technical links across time, and are used in social practices that extend beyond the economic and technocratic.

5.3 The Use Wear Pilot Study

5.3.1 The Experimental Reference Collection

The experimental reference collection was created from coastal limestone and secondarily deposited alluvial basalt cobbles collected in the immediate site vicinity of TFK. Cryptocrystalline basalt and fine-grained, isotropic, non-porous clastic limestone were selected for the experiments, even though a range of other varieties of these materials, such as hypocrystalline basalt, porous bioclastic limestone and coastal conglomerates are also present in the archaeological assemblage. However, use wear develops differently across different mineral inclusions, and for this pilot study I wanted to limit the number of variables present. The variables selected were therefore as homogenous as possible, given the constraints of collecting ad hoc material in the available area around the TFK archaeological site.

These raw materials were collected over several years, beginning in 2013 and continuing every year until 2016, from eroded coastal terraces as well as the wadi directly to the north of the site (**Figure 5.7**). Many experimental studies have been conducted from basaltic stones in Southwest Asia (Dubreuil 2004; Plisson 1989; Hayden 1990; Procopiou 2002; see Dubreuil and Savage 2014 for a synthesis and Chapter Two for list of further citations); far fewer have been conducted on coastal limestones or sandstones (but see Hamon and Le Gall 2012). This is based on the widespread assumption that most limestone and sandstone surfaces are too friable or soft to hold use wear traces over millennia, or else that they will become too obscured by wear marks from post-depositional processes. However, as the ground stone assemblage at TFK is comprised almost entirely of these coastal materials, it was necessary to design a reference collection that tested those assumptions. A lower number of basalt tools were included as well, for comparison, but the study focused on coastal limestone.

Microscopic use wear analysis is based on tribology, which studies primarily two dimensions of modification caused by friction: the physical and the chemical (called tribochemical in most use wear studies). The physical includes changes to grain structure and overall micro-topography of the stone surface through the different kinds of kinetics associated with different textures of materials (**Figures 5.8-5.9**). Tribochemical wear is generally seen in the development of "micropolish," which is not a true polish but rather the build-up of residue on the surface of tools in the form of a film or oxide residue (**Figure 5.10)**. With the aid of microscopy, variations in both physical and tribochemical modifications to stone surfaces can be observed and categorized according to the mechanics of their production, which is established via experimental protocol.

Previous experiments have demonstrated that use wear observations without residue analyses to support them best indicate the most likely texture categories of the materials processed by stone tools, rather than for identifying the specific materials themselves. Use wear patterns – both physical and tribochemical – depend on the consistent friction between specific types of materials over an extended period of time (Semenov 1964; Dubreuil et al 2016). These wear patterns have been experimentally shown to be consistent within texture groups; for instance, materials with soft, oily textures like animal hide have been shown to produce continuous, smooth surfaces with no contact boundaries between plateaus and interstices on the microtopography, because the material is flexible enough and excretes enough oil to get into those spaces and smooth them out (Dubreuil 2004; Adams 2006; **Figure 5.8**). On the other hand, materials with highly abrasive textures like ochre create uneven, discontinuous surface microtopographies with significant large grain damage that tends to level some areas but create grain loss in others, and leave micro-striations (linear traces, often from scratches of stone on stone or the abrasive material itself during processing). The specific attributes of these wear patterns are affected by the material of the stones and intensity of the processing activity. Once wear patterns that are diagnostic to texture categories for a material type can be identified, then residue sampling and other evidence from the site can be brought in to assess more specific likely material candidates for tool use.

However, since many grinding tools are used for multiple purposes during their use lives, and those different uses leave different cumulative patterns, it is often more meaningful to think of how use wear patterns can reveal the changing use of stones over time. Weakly developed versus overlapping wear patterns can indicate whether stones were used consistently for long time periods, or used lightly and then reused for the same or for different purposes, as well as a range of other kinds of use strategies and the degree of labor that might be required for those kinds of uses (Adams 2014; Dubreuil and Savage 2014; Marreiros et al 2015). This is particularly pertinent for the study presented here, as we can temporarily disregard the question of what *exactly* was being processed and instead investigate which techniques of processing, seen via the trace indicators for texture categories processed, were used repeatedly over time. Those techniques, their reuse over time, and the preservation or discard of tools that afford those techniques may indicate how technical knowledge and opportunity was valued and stored over time in the tools associated with multi-generational production mechanics – including but not limited to the processing of agricultural resources.

The original experimental reference collection was created, the protocol generated and testing undertaken at Trent University in Autumn of 2013, under the supervision of Dr. Laure Dubreuil during a visiting research post in her ground stone analysis lab. For this protocol, three initial processing material texture categories were defined and tested based on parameters that were predicted to be clearly distinguishable: smooth/granular (barley), abrasive (rock salt), and oily (flax) (**Figure 5.11**). Although the coastal limestones used at TFK especially, but also at Sidon, vary in composition and (local stratigraphic) origin, samples were chosen for the experiment that were as closely similar as possible to reduce the variables in the testing. The experimental protocol and observation notes are presented in **Appendix Two**. More nuanced texture categories were identified and tested in 2016, once an appropriate high-powered microscope was procured by the Archaeology program at the American University in Beirut. These included splintered/oily (goat bone), soft/oily (goat skin), and smooth/abrasive (toasted chickpeas) (**Figure 5.12**). Because there was no DIC prism available on the AUB microscope[21] the micro-polish could not be observed as well on these stones or the archaeological examples as it was on the original examples at Trent University; however, the fact that a few instances of micro-polish could be observed even without this specialized prism demonstrates that this a good start to the research and a point that can easily be expanded upon in the future. Multiple photographs at very slightly different degrees of magnification (using fine focus adjustment)

[21] This is the most expensive prism to purchase and will hopefully be added later, but the development of a microscopy lab for the archaeology program is still very new. A Differential Interference Contrast prism (DIC, also known as a Nomarski prism) separates and then recombines polarized light before it hits the viewing plane, thereby enhancing the contrast of transparent surfaces. This brings micropolish – as distinct from general surface reflectivity – into a higher relief that can be better observed and described.

were taken of each observation area with a Nikon DSLR camera so that an image could be captured of each level of the topography in focus individually. Then these photographs were stacked using Helicon Focus Stacking software, which combines and statistically renders the individual photographs into a single image with all parts of the topography in focus (generally, depending on the quality of the photos), using depth map or pyramid normalization.

At both high- and low-level magnification, clear use wear trace differences were visible in a range of analytical categories, including surface topography, grain wear/damage, reflectivity, discoloration, and micro-polish development (summarized in the experimental observation report form in Appendix Two). Use wear traces were examined and recorded after every two hours of grinding on the experimental tools to observe whether patterns were temporary or sustained, and how differences over time could help inform assessments of the degree of use on archaeological materials. Given the soft and relatively friable nature of the material, these frequent observations were especially important, as the assumption at stake was that this material would “lose” wear patterns over time as more grains fell off or were compressed into the working surface. It is generally agreed that 10 hours is the minimum amount of labor that must be put into an experimental tool for the wear patterns to be considered analytically significant, although more is always ideal (Adams 2014; Dubreuil et al 2016). Each tool presented here was worked for ten hours exactly, to provide time to do a wider range of pilot studies. All reference tools are stored between AUB and with me personally[22].

[22] The two reasons these have not been returned to storage at AUB are a) stone is heavy and expensive to transport internationally, and b) AUB has limited storage as it is, and I am hoping for the development of an archaeology lab where they might be useful references before shipping them back.

Experimental Ground Stone Use Wear Pilot Study								
	Raw Material	Micro-topography	Grain Damage	Reflectivity	Striations	Discoloration	Micro-polish	Texture Category
Barley	Limestone	Sinuous, even levelling areas, smooth with some roughness in base of interstices, rounded plateau/interstice boundaries	Crushing, compression of grain powder into durable plateaus	General, low to moderate "sheen"	Few, isolated	Some irregular "yellowing"	Yes, very distinct and possibly diagnostic: isolated to powder-plateaus, flat, striated, well-developed	Granular/smooth
Flax	Limestone	Flat, smooth surface with moderately abrupt plateau/interstice boundaries , even in center, uneven toward edges	Some grain loss, limited compression	General, moderate to high	Yes, isolated (from stone-stone contact)	Overall darkening	Yes; discontinuous, flat, highly directional	Oily
Rock Salt	Limestone	Flat, fused, flaky "double relief," or surface flattening at one level, abrupt edges, and interstices on a different level below. Irregular smoothness, low continuity between plateaus and interstices	Flattening and compressing/fusing on the plateaus, in which there is some flaky buildup of compressed grains but it is looser, less fused	Generally matte, but reflectivity especially along the edges of plateaus, some isolated highly reflective rounded grains	Yes, both isolated and clustered, intersecting	Discontinuous areas of darkening	Yes, but weakly developed.	Abrasive
Toasted Chickpea	Limestone	Sinuous, irregular smoothness/roughness, some flakiness	Crushing, compress-ion	General, low	Yes, isolated	Occasional yellowing, isolated areas	Yes, weakly developed across plateau edges and sides	Granular/abrasive
Goat Hide	Limestone	Very smooth, sinuous, even	None; very minor grain loss	General, low shininess with some highlighting along edges of plateaus	No	Yellowing, discontinuous	Very weakly developed after 10 hours	Oily/soft
Goat Bone	Limestone	Smooth, flaky	Crushing, compression	General, moderate to high	Yes, irregular, clustered	Rarely	Weakly developed, degrades easily with increased wear	Oily/splintery (abrasive?)

Table 5.1: Generalized descriptions of observation criteria for different use wear traces on each experimental material, with assigned texture category

The use patterns did show some development over the course of processing, including degradation of some categories of wear development, shown by the images in **Appendix Two** comparing use wear analytical categories after 2 hours and 10 hours of processing for each material. However, while the extent of the wear patterns and the extent of visible development varied, the patterns themselves did not change. For instance, for barley, a strong micropolish developed across the surfaces of isolated crushed-grain plateaus after only two hours of grinding.

Clear multi-directional striations were visible within the micropolish, which was otherwise flat and smooth at a magnification of x400-500 under DIC illumination. After six hours, that polish no longer covered the entire surface of the plateau, and had developed into irregular patches on the surfaces of other plateaus. However, the plateaus remained present and did not themselves vary greatly in size or shape after 2 hours (in other words, the morphologies taken on by the crushed-grain plateaus after 2 hours of processing were those that held for the rest of the processing time). The smooth texture and directional striations within the micropolish also remained the same. Therefore, the texture, striations, and boundaries of the micropolish are criteria that remain applicable and unique to the grainy/smooth category, whereas the total extent of grain/plateau coverage is not; on the other hand, the development of the extent of micropolish coverage may be useful for assessing intensity and longevity of tool use.

Once the range of wear criteria and their applicability to processed material texture categories at various stages of use was established, these could be compiled into the reference standard sheet seen in **Appendix Two**, and used for comparison with archaeological tools. A selection of ten grinding tools from EBA contexts at Sidon and ten tools from EBA contexts at TFK were selected for this pilot study. For each of these tools, at least two different locations on the surface were sampled for microbotanical residues[23] and spot-cleaned using distilled water and a soft toothbrush.

[23] These residues were originally intended to be included in this dissertation, but time constraints prevented this. Most of the residues contained starches and some had a few phytoliths as well, although typically the phytoliths were non-diagnostic psilate long-cells. The results of the residue analyses will be developed for publication elsewhere. The methods for their extraction and point-cleaning are described in Chapter Two.

5.3.2 The TFK Use Wear Observations

Of the ten archaeological grinding stones selected for microscopic use wear observations from TFK, eight were limestone and two were basalt. It was first intended to observe entirely limestone tools from TFK, since a) they were available and dominant in the assemblage, b) they would be best comparable with the original experimental reference collection, and c) they are underrepresented in archaeological use wear studies. However, given that the Sidon assemblage is almost entirely basalt, the purpose of the dissertation project is to compare the two sites, and time constraints made it impossible to compare a full pilot study for both limestone and basalt, this balance was selected as a compromise. The limestone tools selected were those which most closely matched the composition of the experimental tools, rather than for specific contextual purposes. Any pilot study is imperfect, but the results here already show potential for future work.

All limestone tools had microscopic wear patterns consistent with those observed experimentally, although in many cases the archaeological examples were more weakly developed. This phrasing can be somewhat misleading: “weakly developed” does not necessarily mean that the archaeological tools were used more weakly, less frequently, with lighter contact, etc. Rather, it is used to differentiate the types of wear that develop at a slower rate over time but are more consistently held on stone surface once they have developed. Often strongly developed wear traces are those resulting from immediate impact or friction processes and so seem dramatic at the time, but degrade, are worn down, or develop into something else over time. This is methodologically important, as it demonstrates that long-term, weakly developed wear is indeed identifiable on limestone tool surfaces after thousands of years. While it is certain that the wear patterns have been affected by taphonomic processes, the softness of the material is in this case actually also a strength - the underlying patterns are consistent across the use surface areas, and post-depositional damage to those surfaces is very visible in strongly developed but fragile isolated instances. In the case of the harder basalt materials observed, there was less visible surface degradation or damage, but there was also greater patina development that in some cases obscured the difference between underlying use patterns and post-depositional processes.

Of the ten archaeological tools observed, seven were observed to have wear consistent with granular/smooth processing, two have wear consistent with oily/smooth processing, and one has mixed wear that is probably the cumulative effect of different uses on the same surface. Of the seven grainy/smooth textured tools, five have secondary abrasive wear (from stone on stone or abrasive material contact) on top of the grainy/smooth wear. The oily/smooth tools have no signs of primary or secondary abrasion. The multi-use tool has secondary wear in several places, but again, it is consistent with many of the aspects of the experimental wear and so cannot be strongly identified to a texture category.

TFK Ground Stone Use Wear Pilot Study								
	Raw Material	Micro-topography	Grain Damage	Reflectivity	Striations	Discoloration	Micro-polish	Texture Category
Stone 1	Limestone	Sinuous, even	Crushing, compress-ion	General, low	No	No	No	Granular/smooth
Stone 2	Limestone	Sinuous, undulating	Crushing, compression, grain loss	General, low	No	No	No	Granular/smooth
Stone 3	Limestone	Sinuous, undulating	Crushing, compression, grain loss	General, low, higher along plateaus	No	Yes	No	Granular/smooth
Stone 4	Limestone	Sinuous, even	Crushing, compress-ion	General, low	No	Yes	Yes	Granular/smooth
Stone 5	Limestone	Sinuous, even	Crushing, compression	General, low	No	No	No	Granular/smooth
Stone 6	Limestone	Sinuous, even	Crushing, compression	General, low	Yes	No	No	Granular/smooth
Stone 7	Limestone	Sinuous, even	Crushing, compression	General, low	No	No	No	Granular/smooth
Stone 8	Limestone	Flat, sinuous, smooth	Crushing, compress-ion	General, moderate, higher along plateau edges	No	No	No	Oily/smooth
Stone 9	Basalt	Sinuous, even	Grain loss	General, moderate, higher along plateau edges	Yes	No	Yes	Oily/smooth
Stone 10	Basalt	Sinuous, even	Crushing, grain loss	General, low	Yes	Yes	Maybe	Mixed results
Stone 1 = broken limestone slab 265.320.23; Stone 2 = broken limestone slab 285.380.176; Stone 3 = broken limestone slab 310.295.697; Stone 4 = broken limestone handstone 260.325.112; Stone 5 = limestone handstone 310.295.158; Stone 6 = broken limestone handstone 295.300.50; Stone 7 = broken limestone slab 310.295.90; Stone 8 = broken limestone slab 290.310.55; Stone 9 = broken basalt slab 285.295.176; Stone 10 = complete basalt handstone 285.295.196.								

Table 5.2: Summarized general criteria observed for archaeological stone tools from TFK during the microscopic use wear pilot study.

Already, before going farther, we can see that secondary use and reuse appear preliminarily to be isolated to tools used for particular kinds of processing and not others – those used for granular/smooth texture processing appear to be specifically reused more extensively than oily/smooth processors, show isolated wear traces used for other purposes during the stones' primary use lives, and are reused after (sometimes intentional) breakage. This probably places them in a tool category alongside the multi-use tool in terms of how they were technically conceptualized and used over time; there is a difference, however, in that the predominantly granular/smooth processing tools had a specific primary use and then were re-employed, rather than generalized ad-hoc tools from the start. This already presents us with intriguing preliminary technical categories of grinding tools, and the way different techniques are preserved on a single tool as it becomes worn over time, that are worthy of pursuing with further research.

The cases for granular/smooth wear are identifiable based on several criteria: general topography including reflectivity, boundaries between interstices and plateaus, grain damage and micropolish development (**Figure 5.13**). As established for the experimental tools, the general topography for this texture category is sinuous and even, with soft, rounded boundaries between plateaus and interstices but minimal to no wear in the interstices themselves (except for grain loss). This shows the material had a flexible, medium-soft texture that gave way over the edges of interstices but did not penetrate to the base. It was ground in quantities such that the upper and lower stones did not often abrade each other.

There tends to be a generalized reflectivity that develops across the use surface micro-topography on the experimental granular/smooth and the oily material surfaces that is distinct from micropolish development. Under DIC reflection this gives the appearance of a double-relief across the surface, as the shine appears elevated slightly above the topography (**Figure 5.14).** Under regular cross-polarization, the surface can appear instead to be more strongly reflective, and can obscure the grain texture slightly (**Figure.15**). This reflectivity is a function both of the material itself (the calcareous and quartzitic stone seems to more easily develop a surface shine than the basaltic stone) and also of the continuous soft friction across the increasingly smooth surface. Minimal abrasive traces (striations) are seen, and when they are present they have generally been worn over so that the edges are smooth and the striation u-shaped.

Micropolish develops in a very specific and likely diagnostic pattern in relation to grain damage on the granular/smooth processing stones: soft, fine grains are crushed and compressed together in a powder that accumulates around the pre-existing plateaus (from pecking or natural grain topography) and crystal inclusions to form new, broader plateaus; micropolish develops on the surfaces of these new plateaus (**Figure 5.16**). Importantly, directional striations are most clearly seen in this micropolish, as they are not strongly developed elsewhere on the stone surface for this texture category. While micropolish will shrink in size and expanse over time, it remains isolated to these specific plateaus and the overall pattern remains unchanged. Examples of these criteria from the experimental tools separately are in **Appendix Two**; to see examples of these observations on archaeological tools as compared to the experimental tools, see **Figures 5.13-5.16.**

The criteria for the oily/smooth texture category (tested with flax and goat hide)[24] is best seen in the general topography, reflectivity, discoloration and boundaries between plateaus and interstices. The topography is flattened, smooth and sinuous, such that any shallow or undulating plateaus are eliminated, and only deep interstices remain. The boundary between plateaus and interstices is extremely smooth, as is the surface texture of the interstices themselves, typically all the way into the base. This shows that the material used was soft and flexible, and secreted enough oils, to extend the wear into the interstices to the base. A generalized highly reflective shine develops across the surface, with discrete instances of flat, straight, linear, and strongly directional micropolish on the flat surfaces (seen in the experimental tools more clearly than the archaeological tools). Discoloration is seen in the development of discontinuous dark yellow

[24] This is not analytically significant (most likely) but the goat hide smelled the worst during processing than any other material tested, if any future readers are interested in the sensory aspects of these techniques.

areas across the flattened surface. **Figure 5.13** shows examples of these observed characteristics compared between experimental and archaeological tools. There are occasional linear striations that indicate stone on stone contact (i.e., the material did not always cover the whole use surface while upper and lower stones were in action). It is also possible that these indicate an oily/abrasive material was processed as well, such as animal bone, which would leave striations and and oily texture on the micro-topography. In that case, however, the striations would likely be more frequent and multi-scalar (differences in length, depth, clustering, etc.).

Importantly, one of the TFK tools showing characteristics for oily/smooth texture processing comes from a grinding stone found inside a cooking pot (285.295.176). This flat, thing, ovate basalt slab has been described in detail elsewhere (Damick in Genz et al 2009). Here it is interesting to note that this morphology is very similar to those proposed by Baysal (as described above) as cooking slabs, rather than grinders. In a cooking context, if this were a cooking slab used for roasting meat, for instance, instead of for grinding or scraping, the oils from the meat would saturate the surface over time, which could potentially create a similarly smooth, sinuous, highly reflective surface. This is an aspect of stone use wear that has not been thoroughly covered experimentally, and therefore criteria to distinguish passive oil uptake from active oil distribution via hide, bone, or oily plant processing, for instance, is not yet available. However, this is an instance where context might help illuminate other possibilities for the development of established use criteria in a way that the use wear alone categories have not yet covered, and conversely, the use wear observations help to back up the contextual interpretation.

5.3.3 The Sidon Use Wear Observations

Two limestone and eight basalt broken grinding stones from Sidon were observed microscopically. Of these, the two limestone tools both show characteristics for granular/smooth texture wear. Of the basalt, three show granular/smooth, three show a combination of granular/smooth and abrasive, and two show smooth/oily texture characteristics. The analytical wear characteristics that could be observed on these stones included microtopography, reflectivity, grain damage, discoloration, and micropolish (rarely). These characteristics are as described above for limestone.

Sidon Ground Stone Use Wear Pilot Study								
	Raw Material	Micro-topography	Grain Damage	Reflectivity	Striations	Discoloration	Micro-polish	Texture Category
Stone 1	Basalt	Sinuous, even	Crushing	General, low	Yes	No	No	Granular/smooth Abrasive
Stone 2	Basalt	Sinuous, even in center/ uneven toward edges	Crushing, grain loss	General, low	Yes	No	No	Granular/smooth Abrasive
Stone 3	Basalt	Flat, sinuous, smooth	Smoothing	High along edges of plateaus	No	No	No	Oily/smooth
Stone 4	Limestone	Sinuous, even	Crushing, compress-ion	General, low	No	Yes	Yes	Granular/smooth
Stone 5	Limestone	Sinuous, even	Crushing, compress-ion	General, low	No	No	No	Granular/smooth
Stone 6	Basalt	Sinuous, even	Crushing	General, low	Yes	No	No	Granular/smooth Abrasive
Stone 7	Basalt	Sinuous, even	Crushing, grain loss	General, low	Yes	No	No	Granular/smooth Abrasive
Stone 8	Basalt	Flat, sinuous, smooth	None/ smoothing	High along edges of plateaus	Yes	No	No	Oily/smooth
Stone 9	Basalt	Sinuous, even	Grain loss	General, low	No	Yes	Yes	Granular/smooth
Stone 10	Basalt	Sinuous, even	Crushing, grain loss	General, low	No	No	No	Granular/smooth
Stone 1 = broken basalt slab 2387.2127; Stone 2 = broken basalt slab 5856.2295; Stone 3 = basalt handstone 2280.4507; Stone 4 = broken limestone slab 4027.2093; Stone 5 = limestone handstone 4508.2280; Stone 6 = broken basalt handstone 4566.2285; Stone 7 = broken basalt handstone 4686.2301; Stone 8 = broken basalt slab 5326.1301; Stone 9 = broken basalt slab 5406.2301; Stone 10 = broken basalt slab 5652.2340.								

Table 5.3: Summarized general criteria observed for archaeological stone tools from Sidon during the microscopic use wear pilot study.

As for the TFK stones, the archaeological stones observed did not necessarily present all of the characteristics seen on the experimental stones for a particular texture category. Some variability is to be expected – human/tool interaction is not a fixed mechanical process. To determine the primary texture category of use, the analytical characteristics were considered together and assigned to the texture category with which they overlapped the most.

Notably, a significant number of the grinding tools from Sidon that were assigned to the granular/smooth category also had abrasive characteristics, such as striations and occasional abrasive grain crushing. This would occur either in cases where the quantity being ground was so small that the upper and lower stones were constantly coming into contact, which is certainly possible but also inefficient and uncomfortable for the person doing the processing. It seems unlikely that this technique would have been maintained over time, as it would have been jarring to the body as well as the production process. It has been demonstrated elsewhere that repetitive grinding activities have long-term impacts on the skeletal development of regular practitioners, which leave detectable biarchaeological markers (Molleson 2007; Wesp 2015; for a case from Peru: Klaus et al 2009). Strategies like elevating grinding stones on plinths while processing were undertaken to alleviate such discomfort, as at Catalhöyük and Ebla (Molleson 1994); it seems improbable that a more painful alternative would have been maintained.

It seems more likely, then that these striations are indicative of different uses for these stones at different times, which left overlapping use wear patterns. The generalized granular/smooth microtopography suggests than the primary activity was grain or pulse grinding, the elevated reflectivity along the edges of the plateaus in Stone 3, for instance, is more comparable to oily textured materials and the use of high-pressure kinetics that increase the friction to the edge of the plateau. This is also, for instance, how the extremely sharp edges of two-handed hand stones are produced – heavy pressure on a narrow upper stone above a wider open lower stone will create a very flat use surface and a very sharp edge (personal observation). The striations show some kind of abrasive material was present, as does the large grain damage.

This suggests that like the TFK toolkits, these stones were not uniquely specialized to a single type of use kinetics, but that tools used primarily for grain grinding, for instance, were also co-opted at least occasionally for crushing purposes as well, likely of bones or nuts, which would combine the abrasive and oily characteristics seen as secondary use on these surfaces. On the other hand, there are far fewer instances of reuse over broken tool edges on these stones than there are at TFK, indicating that their use lives were either shorter or intended specifically for stationary activity. I do suspect that a bias in identification and collection of fragments may affect our understanding of how significant this really is, and I hesitate to draw too much inference about differences in mobile toolkits. That issue aside, this is interesting as it demonstrates that even though the Sidonian population was actively trading for basalt for their grinding tools, the techniques employed and strategies of use for these grinding stones do not reflect major differences from the smaller contemporary settlements.

The oily smooth texture category here is represented by two partial basalt tools. The characteristics of smoothing and reflectivity across the microtopography and extending into the bases of the interstices is similar to that seen on the TFK stones. However, a critical difference that is related to material type is in the large grain damage. While the limestone tools at TFK showed evidence of crushing (powder) and compression (powder filling interstices and forming new plateaus) even with the softest material texture categories, the basalt does not show these kinds of grain damage. The harder grains found in the mineralogical makeup of the basalt grinding tools becomes increasingly smooth over time, creating an increasingly viscous texture across the surface, but the grains do not fall out, become crushed, or compress into interstices. One of these stones (Stone 3) comes from Room 6 in the EBA mud brick building, which may be a terrace-like area that is only partially enclosed, and appears to be largely dedicated to cooking: it contains two hearths on a partially paved, packed earth floor. Again, context gives us a clue here, and in this case in one in which we might do well to consider the possibility that these tools were part of cooking, and not just grinding, in the life cycle of processing foodstuffs.

5.4 Comparison and Discussion

The preliminary results of this pilot study demonstrate several important things. First, they prove the feasibility of pursuing use wear analysis of coastal limestone archaeological tools. Second, they establish a range of use wear characteristics on Lebanese coastal limestone for six different texture categories, four of which have also been found represented on archaeological material. Third, and most importantly for our purposes here, they indicate that there may have been some kinds of tools that were only used for single processing techniques and discarded without reuse, and others that were reused for the same or secondary processing techniques over multiple breakage episodes.

It is a unique feature of grinding stone tools that they survive for many generations. Their durability can be a challenge – as described earlier, it makes dating them as archaeological artifacts much more difficult, for instance, than dating other material culture types. Often, grinding tool morphologies do not change dramatically over time, either, unless you are working with a very long analytical timeframe. However, these very characteristics that have caused grinding tools to be dismissed as irrelevant or impossible to apply to diachronic research are just the characteristics that make them so critical to thinking about how long-term technical memory is stored and transmitted. As stones are passed down through generations – either whole or in fragments – they carry with them the memories of their past use lives, as well as the technical affordances and knowledge that are brought along with them. There is ethnographic and archaeological documentation from around the world showing how grinding tools form part of the equipment passed down as inheritance, often from mother to daughter (Mesopotamia: Potts 1997; Turkey: Sharovskaja 1999; Central Africa: Corbeil 1985; Southwest United States: Adams 1994, 2006). Along with these accounts come those discussing the teaching of grinding as a kind of specialized and often gendered knowledge (Lion and Michel 2016; Stol 2016). Among Zapotec communities in Mexico, a set of grinding tools is a traditional wedding gift, with the handstone referred to as the child of the new marriage. The relationship between the handstone and the grinding slab was a metaphor for the close bond and reciprocal influence between mother and child (Parsons 1970; Holmberg 1998).

Although we do not have enough information about gender and gendered labor in Bronze Age Lebanon to definitively discuss these tools in that context, it provides an avenue for thinking about the ways in which knowledge can be stored in a tool and only brought out of storage within specific contexts and for specific practitioners. The pattern seen at TFK and at Sidon is that tools showing microwear traces consistent with grain/pulse processing are those most frequently reused and curated over time. Tools associated with processing oily/smooth or oily/abrasive materials, such as bone, hide, or nuts, do not show such signs of reuse over time. This lends another layer to the notion of what knowledge resides within a tool, for whom, and when; perhaps some techniques are stored in the tools of that trade and carry it inter-generationally, and some techniques require the introduction of new tools.

This has implications for broader landscape use, as well. For one thing, the importance of reusing fragments for the processing of smooth/granular materials (likely grains and/or pulses) implies that these were techniques that were needed to be portable as well as stationary, and accords with the phytolith evidence for cyclical use of different parts of the landscape over the course of settlement expansions and contractions. It also allows us to think more critically about fragments not just as ad hoc cobbles procured for a convenient purpose, but as part of tools with longer lives than their human counterparts. This restructures the way we might interpret the demands of a society on geological resource zones in the landscape. Rather than requiring a steady flow of available materials, a combination was needed of durable materials that would last over time, and those that could be discarded more easily, for different purposes.

Another interesting aspect of the ground stone assemblages at TFK and Sidon revealed by this study are that some tools show evidence of intentional breakage: chisel marks are evident on either face of an otherwise still functional tool (i.e., nowhere near the point of exhaustion, and not thin enough to break without assistance) that were used to weaken the center of the tool and provoke a lateral break (**Figure 5.17**). Sometimes reuse is observed over intentional breakage, and sometimes not. Intentional breakage is a phenomenon that is only recently getting the attention it deserves archaeologically (Hoffman 1999; Adams 2008). Examples of intentionally broken grinding stones in the archaeological record are wide-ranging, though under-explored. At Neolithic sites in Sweden, for instance, many of the grinding tools deposited in ritual pit deposits are interpreted as having been broken before deposition in a “killing” and burial of the stone (Karsten 1994:25—26).

Jenny Adams has also written of intentional breakage and the symbolic “killing” of the grinding slab among the living and ancestral Native communities of the North American Southwest (Adams 2008). She invokes the explanation of Santa Clara Puebloan potter Rina Swentzell, who explains that her community thinks of human-made objects like pots as living and breathing in the same way humans, animals, and plants do, and therefore they must have holes drilled into them before discard in order to “allow the breath to flow back into the cosmos” (Adams 2008: 215; Brody and Swentzell 1996: 20-21). This type of perforation is one way to responsible “kill” an object; another is to fracture it into many pieces, and keep those pieces near each other or distributed to specific people so that the memory of the whole object remains intact (Chapman 2000).

Alongside the evidence for broken grinding tools deposited in special pit contexts at Sidon, this evidence should invite us to think more critically about the role that broken tools had in preserving forms of memory across different contexts. While we certainly cannot draw direct parallels with Swedish Neolithic or ancestral Puebloan beliefs and practices, these examples should help us to broaden our understanding of grinding tools as multi-generational mediators of human-land relationships, objects which stored within them memory and meaning, as well as functional purpose and skilled technical knowledge.

5.5 Geological Resource Zones

Ground stone tools are one of the most infrequently studied artifact categories in archaeological research, as discussed above. This is particularly true for periods post-dating the Neolithic; during and before this point, grinding tools are often seen as part of the ‘toolkit’ accompanying a widespread transition from hunter-gatherer to agricultural lifeways, and therefore are seen to have value for understanding transforming local economies. After the point at which researchers perceive agriculture to have been safely established, grinding tools attract less interest and fade back into the appendices of site reports, if they are reported at all. Although the past few decades have seen a growth in attention to ground stone artifacts in different ages, spurred on particularly by the promise of new techniques in use wear and residue analyses, they remain largely represented by their absence in the archaeological literature. Only recently have any ground stone studies focused on material from Lebanon (and these are partial and preliminary: Damick in Genz et al 2016; Damick in Genz et al 2009; Damick in Genz et al 2010; Bofill et al 2013), and few focus on material from the northern Levant more broadly (Bofill et al 2013; Arnold et al 2017). Studies on ground stone from the Early Bronze Age in the Levant more generally are also infrequent (but see: Williams-Thorpe and Thorpe 1993; Abadi-Reiss and Rosen 2008; Milevski 2008; Rosenberg and Golani 2012; Beller et al 2016).

In addition to their role in a preliminary functional analysis based on use wear, as above, the grinding tool assemblages at TFK and Sidon are of interest for the range of raw materials they represent, and how that changes over time in relation to settlement development and vegetation zone use as described above.

5.5.1 Raw Material Types

Six general raw material categories are identified in the ground stone assemblages from TFK and Sidon: coastal sandstone (*ramlah*), limestone (for the purposes of this chapter, coastal coastal marls and conglomerates are included with limestone), volcanic rock (including basalts, tuff, and pumice), chert, quartzite, and other (including rare examples such as siltstone, steatite, etc.). The methods and criteria for these types is described in Chapter Two. In this chapter, these raw materials are drawn upon to identify possible geological resource zones in Lebanon that were accessed for the production of these tools: coastal, volcanic outcrop, foothills and low mountains, and non-local (i.e., from outside Lebanon). It should be remembered that both Sidon and TFK sit on alluvial fans, the outlets of waterways coming down from the mountains, and are surrounded by unstable alluvial and coastal sections with evidence of ancient erosion and water transport (Pustovoytov 2011). Thus a good portion of these materials may have traveled down to the site area through those processes of erosion and water transport, making them available locally.

This data is therefore intended to provide a starting point for further research on the relationship between communities in different areas of Lebanon during the EBA (especially the mountains, foothills, and coast), and how materials deriving from different parts of the landscape came to be preserved and curated over time, but is in no way conclusive. Hopefully future research incorporating off-site geoarchaeological survey as well as other kinds of stone objects from these sites can broaden our understanding of the relationship between resource and land use. A geological map and cross-section of Lebanon are visible in **Figures 1.3** and **1.4,** introduced in Chapter One, for references made in the following section to areas where they resources are available.

5.5.2 Tell Fadous-Kfarabida Raw Materials

The vast majority of ground stone objects from Tell Fadous-Kfarabida are made of local coastal limestones and limestone-marls, which are abundant in the immediate vicinity of the site and along the length of the Lebanese coast. Other materials used for the processing tools include calcareous coastal sandstone ("*ramlah*"), quartzite, chert and volcanic rocks including basalt and tuff . Of the attested raw materials, only the volcanic rocks are not available in the immediate site area; the nearest volcanic outcrops are in the Akkar area north of Tripoli, or farther to the south near Mount Hermon. As TFK lies on a coastal strip of exposed Sannine limestone overlaid by fluvial runoff containing mixed pebbles and boulders, everything else in the represented range of materials would not have been difficult to locate and extract (Nader in Badreshany et al 2005). The distribution of raw materials by tool type is presented in **Figure 5.18.**

Existing evidence in Lebanon suggests this preference for limestone over basalt grinding tools is somewhat unusual, as neighboring contemporary sites like Byblos, Arqa, and Sidon seem to have preferred basalt (Dunand 1958; Dunand 1973; Bofill et al 2013; Doumet-Serhal 2006b; pers. obs.). This should be taken with some degree of caution, since, as mentioned above, this may be a function of identification during collection processes, and in the southern Levant, preference for locally available materials during the Early Bronze Age is quite common (Ebeling and Rowan 2004; Milevski 2008).

If we accept the face value appearance that TFK is an anomaly in terms of raw material preference for grinding tools, there are a variety of explanations we might look to. First, it may seem to be explained by the site's distance from naturally occurring basalt sources. However, this does not seem to have been a problem at Byblos, with which site TFK was likely administratively linked. Any explanation based on distance, then, would indicate, then, that larger settlements such as Byblos or Tell Arqa acted as centers for non-local lithic resource distribution, and controlled the transport of volcanic stones; on the other hand, access to locally sourced coastal stones did not apparently fall under such restrictions.

It is also possible that the rough, fossiliferous surfaces of the local limestone was sufficiently coarse to mimic the desireable texture of basalt, and to reduce the need for constant re-pecking that often characterizes relatively soft limestone tools (see Chapter Five). Likewise, limestone tools could easily be replaced when worn, which means they may be somewhat overrepresented in this particular assemblage. Preliminary experiments do demonstrate that the local limestone used for grinding tools during the Early Bronze Age leaves a significant fine powdery residue in most materials they are used to reduce (Damick in preparation). This is something that inhabitants would certainly have been aware of. Previous studies have often postulated that this is an undesirable characteristic of limestone, as with harder limestones and sandy conglomerates, the loose grains in such powder have been shown to have caused significant dental damage when consumed along with the ground flour (Eshed et al 2006; Mahoney 2006). It is not clear if this softer, powdery residue has similar long-term effects, and it remains unclear if this was selected for via raw material choice or if people became habituated to it out of necessity, given a restriction on other raw materials.[25] In any case, the residue does not

[25] Preliminary grinding experiments were carried out using locally-sourced limestone to manufacture grinding tools and then grind materials of different textures. Some of the flours obtained from these experiments were then baked to test variation. Different use wear patterns were distinguished according to the materials ground; the full results of this study are in preparation for publication, and will hopefully be available soon. I found no discernable effect on flavor or texture, but long-term results would obviously be quite different. We await the discovery of local EBA burial grounds, for dental microwear studies and many other research questions of interest.

in any way seem to have impacted the intensification of use of limestone as a grinding tool material throughout the EBA occupation of the site.

Local raw material was used expediently and without much concern for frugality. Grinding slabs and handstones were commonly produced on limestone and sandstone boulders or cobbles that naturally occur in a range of sizes appropriate to these tools. These boulders and cobbles were minimally worked prior to use. The extent of manufacturing included some flaking for size reduction and rough shaping of the blank, followed by abrasion to smooth the edges and occasionally to level the base of stationary tools. Further preparation includes pecking a general use surface (or two) and then the natural reduction of that area through continuous use, typically via grinding or crushing action. Almost all grinding slabs had open use surfaces. No clear debitage or early stage blanks have been found on site thus far, so it remains unclear if these manufacturing stages were conducted inside or outside the main settlement area. Many of the tools are only minimally used, however – certainly nowhere near the point of exhaustion, and yet they were left behind when occupation transformed and many of the rooms were given up. This further underscores the ease with which such material could be replaced, and the unconcern inhabitants had about accessing more such material even after the EBIII settlement contraction. Given that many of the tools are made from the same limestone material as was used for building construction on site, it is likely that a quarrying area existed, from which leftover raw material could easily be preserved and used for grinding slab production.

Mortars required slightly more extensive manufacture. They were also originally roughed out of limestone blocks, likely flaked off larger boulders (sometimes their irregular and unfinished shape indicates this). They were then flaked into a generally round shape and roughly abraded before the internal concavity was attempted. While this may sometimes have been produced via chiseling and/or basket-hopper shaping (Buonasera 2016), drilling technology was also present on site (Damick and Woodworth 2016; Damick in Genz et al 2009, 2010, 2016) and was certainly employed in some cases.

Non-tubular drilling is evidenced by one incomplete limestone bowl with clear concentric descending concave drill scars, with no core removal protrusions on the base, found in a fill level likely from the latter part of Phase IV in Building 4, and several small perforated stones. The basic morphology of limestone bowls and mortars is the same throughout the EBA; the distinction is based entirely on the interior wear (mortars show percussion and abrasion wear on the base of the interior concavity, vessels do not, as per Wright 1992) and the finishing of the exterior (vessels are generally more finely finished). Thus, the unfinished vessel demonstrates one way in which this general form was being produced on site that likely applied to mortar production as well. In any case, neither bowls nor mortars are standardized, and they have no complex attributes (such as bases, handles, or decoration). In fact, almost all instances of more extensively manufactured ground stone objects of locally derived materials appear to be incidental, produced on a case by case basis, rather than part of a larger, more specialized production industry.

While local stones make up by far the highest percentage of complete and incomplete (broken but not reused) objects found on site, they make up a relatively low percentage of the tools that were found to have been reused after breakage. However, in some cases they are reused in other ways, primarily architecturally: for example, a grinding slab is used in a building wall or mortars as a column bases. There are clear distinctions between unique variations in local materials as well; the grinding slabs reused in the walls and the mortars reused as column bases are the same kind of fine-grained, hard limestone used for wall stones. Soft, friable limestones are only used for handstones, whereas medium hard-hard limestones and conglomerates are used as milling stones. The "miniature mortars"[26] are an especially stark example of this attention to local coastal material variation. These small mortars, ranging from 5 to 15 cm in diameter, are exclusively made from very rough, loose coastal sandstone. This is a type of coastal sandstone distinct from the more well-formed, compact *ramlah*, but not significantly more rare or inaccessible. No other artifact type is made from this material, however, suggesting it was specifically sought out for miniature mortar production. The mortars have small, sometimes quite shallow internal concavities and show minimal signs of extensive use or reshaping (although this particular material is quite friable and therefore signs of reuse may easily be lost). Use and function are further described in Chapter Five; here they are introduced to emphasize that material classes were being intentionally selected for particular tools, and not just expediently procured, even within the locally available coastal stones. This represents a complex relationship to local lithic landscapes – on one hand, there was confidence enough in the availability of coastal materials to limit the need to reuse older or broken tools, but on the other hand, very specific variations in the material were sought for specific tool types.

Basalt tools present a different scenario. These were probably manufactured off-site; there is no evidence of local manufacture, nor any unfinished products or basalt debitage. As there are no known basalt outcrops anywhere in the site vicinity, the likelihood of manufacture at

[26] Also called "cupmark mortars" in some reports (Wright 1992), but here called miniatures to emphasize size as the primary morphological distinction, and to avoid confusion with cupmark bedrock mortars (i.e., Nadel 2009; Eitam 2015).

a local quarry can be eliminated. Basalt dominates the fragments present on site to an extent that is disproportionate to its overall representation in the assemblage, suggesting broken basalt was kept on site much longer than broken tools of other materials. Furthermore, a high percentage of the broken basalt tools are carefully curated and reused, but not extensively reshaped, indicating that the material was valued but the knowledge for (or inclination to) work it extensively may not have been locally present (Chapter Five).

The role of local raw material in the assemblage is clearly significant. Numerous studies, including ethnographic, historical, and chemical proveniencing, document the long-distance trade throughout history of non-precious stone as a raw material and as a finished product, even when local resources suitable for purely utilitarian purposes were readily available (Weinstein-Evron et al 1999; Williams-Thorpe and Thorpe 1993). As early as the third millennium BCE, texts from Mesopotamia record the importing of handstones (Pettinato 1972:73-8, quoted in Milevski 2008: 117). It is clear that raw material and its provenance in many cases had significance in the production of domestic toolkits that went beyond the purely utilitarian or convenient, and that this significance played a more complex role in the production, use, curation, and discard of ground stone artifacts than has typically been considered for complex, aggregated settlements.

The case at Tell Fadous-Kfarabida appears to be similar; the local coastal stones, although not apparently regulated by a central authority in the same way imported stones were, were clearly managed and selectively exploited for a range of specialized purposes. There is, however, little spatial or temporal distinction in access to local stones throughout the site. There is some evidence of a relationship to foothills, or at least alluvial/deltaic, sources in the low density but fairly ubiquitous presence of quartzite and mountainous sandstone throughout the assemblage. These are in low enough numbers that they may easily represent scavenging from erosional contexts, but they bear further examination as more foothill sites become available for study. Mountain/volcanic resources are, as described, present in very specific contexts but clearly not understood as well as were the coastal materials, indicating they are the source of trade rather than direct sourcing.

5.5.3 Sidon

125 ground stone artifacts were analyzed from EBA contexts at Sidon. This excludes all ground stone from insecure contexts, or clearly of mixed date. As above, dating ground stone at all is challenging, and since the Sidon local chronology is not yet precisely established, the artifacts here are presented for material across artifact type, broadly within the EBA, rather than be chronological distribution. **Figure 5.19** shows the distribution of raw material types across the Sidon ground stone assemblage.

The first thing that should be noted is that volcanic rock (largely basaltic, with some tuff and one pumice example) dominates the assemblage by a significant margin. We must temporarily put aside the reservations established above concerning collection disparities, and deal with what the assemblage presents us with at present. The notable exception to the pattern of overwhelming volcanic rock dominance comes from the mortars – these instead are made entirely from coastal limestone and sandstone, and are further discussed below. There are no examples of fragmentary tools in any material other than basalt.

If we accept that basaltic volcanic rock is the raw material favored by the Sidon EBA community for grinding tools, then this clearly points to a need to maintain access to non-local geological resource zones. For this quantity of volcanic rock, all of it high quality, we can reasonably argue that the runoff from the wadis would not have been a sufficient source to sustain the needs of a rapidly aggregating settlement with extensive processing requirements.[27] Access to these non-local outcrops could only reasonably be accomplished by long-distance trade, as there were certainly plenty of EBA communities established near the closest outcrops of basalt, at the base of Mount Hermon, and in the mountains and hills between, with whom the Sidonian population would have to interact to reach and procure those resources.

This implies a less extensive use of the local coastal geological resource zones than we've seen in the north. The mortars are the only tool type that extensively uses local coastal material, which again emphasizes the particularity in mortar material selection seen at TFK. All the mortars from EBA Sidon are miniature mortars, however; there were no examples of larger-scale or even medium mortars in the assemblage. Of these, only a few were in the rough sandstone used in the north, while the rest were flaked from fine-grained limestone pebbles. We may be seeing local expressions of a regional general preference for limestone pounding tools then, where the coarser material is preferred in the north and there is more variation in the south. The assemblage is too limited at this time to be certain, but bears further comparison as more site assemblages become available for comparison. It seems that specific instances of older local traditions – such as the hunting discussed previously, and here the miniature mortar production – can be seen sustained even as Sidon became a major trade center on the Levantine littoral during the third millennium BCE.

[27] As with all such statements, this seems reasonable given current observations, but such assertions have been proven wrong many times before in archaeology. This would of course need systematic testing to confirm the output of the local alluvial systems and needs of the community, which is beyond the scope of this project.

Even so, the Sidon evidence indicates little need to specifically seek out limestone boulder quarry areas or maintain limestone outcrops in the way one might imagine was necessary in the north. The limited use of coastal limestone for architecture, in favor of mud brick and wood, makes investment in coastal quarrying even less likely. In general, from these results, one can imagine a Sidonian relationship with geological resources in the EBA that was far more oriented towards procurement via distance trade rather than local specialization in procurement or production. This is a less intimate and specific knowledge of local coastal geology in this regard than seen at TFK, but perhaps a more robust trade relationship with foothill and mountain communities. One interesting counterpoint to this, of course, is the dominance of coastal limestone and its variety in the mortars – here it seems that specific forms of local knowledge, likely pre-aggregation and trade expansion knowledge, and local manufacture are preferred and maintained throughout the EBA.

Reused grinding tools are in general less numerous throughout all material types at Sidon than at TFK. Curation over time seems less important, as does preservation of any particular kind of tool or material. Of the reused examples available, however, basalt is once again dominant, although in this case it seems more likely to be related to the ubiquity of basalt in general (and collection) than to excessive care for these materials. When reuse is present, it is minimal and partial, rather than across multiple surfaces and edges as is the case with the TFK material; highly reused fragments are far less numerous overall. There is very little evidence of any relationship to foothills/alluvial resources, as quartzite and mountain sandstone are almost entirely non-existent; any resource transit was focused between the volcanic (and likely Biq'a) ranges and the coast rather than the intermediary zones.

Chapter Six

Storing Authority in the Land: Just relationships of living-to-land, rulership, and resilient society

"Then [Anat] headed to El

At the source of the two rivers,

In the midst of the channels of the two deeps;

She arrived at El's encampment,

The tent of the King, the Father of Time…."

Baal Cycle Tablet III, Column Four, Coogan and Smith (2012) translation

"Now Baal will provide his enriching rain,

Provide a rich watering in a downpour,

And he will sound his voice in the clouds,

Flash his lightning to the earth.

Let him complete his house of cedar! Let him construct his house of bricks!"

Baal Cycle, Tablet IV, Column 5, Coogan and Smith (2012) translation

6.1 Offsetting oppositions in how to live and lead

The juxtaposition, and interdependence, of Baal and El's chosen houses was introduced in Chapter Two as a metaphor for the ways in which younger and older generations depended on the ambitious risk taking of the one and reliability and wisdomof the other, respectively. The importance of links between concepts often thought to be oppositional - the old and new, mobile and stationary, large and small scale - has been a theme throughout this dissertation. As I have examined the evidence for plant and stone use throughout the Early Bronze Age development and occupation of TFK and Sidon along the Lebanese coast, it has become clear that the maintenance of these oppositions are in fact what held life together in a volatile world. This chapter, in lieu of presenting conclusions, draws these lines of evidence back together to think about ways they can help us move towards more productive thinking about both past societies' strategies in relation to their land and resources, but also our own as we confront modern versions of similar kinds of environment-society volatility and the demand for adaptation.

The concept of rulership and authority in the Levant is often discussed by researchers of the second millennium onward, and for all of the regions surrounding the Levant, including Mesopotamia, Egypt, Anatolia, and Crete (Buchholz 1987; Marinatos 1993; Kuhrt 1995' Davies and Shofield 1995; Cline 1998; Kristanssen and Larson 2005). The Early Bronze Age Levant is one that is not frequently invoked in discussions of rulership, as there is so little evidence for what such a role might have looked like, and as much research has considered the Levantine settlements to be too small-scale to be interesting in this regard. Instead, archaeologists – myself included – frequently debate the evidence for the existence of an "elite" based on the presence of prestige goods and apparent differences in access to various resources; i.e., how things were organized and scales of interaction, rather than what it meant to entrust someone or some people to organize them (de Miroschedji 2002; Gophna and Paz 2014).

Current organizational models for the EBA Levant propose that the elite at slightly larger and wealthier settlements like Byblos likely held the authority to control the use of land in different ways and to direct the pathways of resources produced from that land to themselves, smaller settlements within their range of control, and external entities via trade (Joffe 1993; Esse

1991; Glassman 2017; Collins 2016). There was likely a person or family at the head of the elite group, if we interpret the "mayors" of cities cited in later texts, especially the lengthy second millennium BCE Amarna letters from Byblos to Egypt, are rooted in older modes of leadership (Moran 2002; Cohen and Westbrook 2002; Glassman 2017). These later sources emphasize, however, that the king, or whatever title the central political ruler held locally[28], was always in authoritative balance with a "council of elders" from the surrounding community (Glassman 2017; Binetti 2017). I attempt here to think about how that kind of political leadership, a balance between emergent new rulers and traditional groups of elders selected from widespread parts of the land to be governed, might be seen as rooted in earlier socio-cultural relationships to control of land and management of people and land resources. This is, in part, the articulation I have attempted throughout this dissertation between the later Bronze Age texts and the evidence for organized strategies of land use.

Tundenhaft (2012) interprets the Baal Cycle, which I refer to frequently here, as ultimately about Late Bronze Age political relationships. Baal violently defeats the sea god Yamm and on that basis is seeking acceptance as a brother in a confederation of rulers – the other gods – who won't attend his inaugural feast the first time he asks. After he convinces El to let him build a palace, they agree to attend and refer to him as "brother". While Baal's military victory over Yamm technically earns him a place of rulership in the pantheon, and the monumental palace he so desires, it is El's influence that is needed for Baal to rule within the established brotherhood of ruling gods. Military prowess alone is not enough; a relationship to the elder rulers and ways of life must be affirmed. These ruling gods can probably be thought of

[28] This is not flippant or dismissive; we don't know because, again, texts from local Levantine settlements are rare, and external sources may be imagined to have other motives in designating Levantine rulers with diminutive titles.

as the patron city gods commonly worshipped at Levantine Bronze Age settlements; Tundenhaft sees them also as a metaphor for newly emerging rulers of various Late Bronze Age city-states in the region as they attempted to form alliances with more established regional rulers (2012: 19-21).

We must leave aside any notion of direct analogy, of course – the political reality of the Late Bronze Age is much better known that that of the Early Bronze Age and was certainly quite different. However, if we think of the tension held in these stories between old and new authority, we can perhaps extrapolate some sense of the importance of balancing old traditions and relationships to place with new assertions of power. Nonetheless, this offers us a way into thinking about how management of and interaction with the landscape – its botanical and geological aspects especially – extended into broader social and, perhaps, political and administrative roles that had long-reaching consequences. The notion that social roles can be emergent through behaviors, rather than fixed assignments, is something that has been extensively examined in anthropologies of the modern world[29]; in many ways, however, we find it expressed elegantly in the Bronze Age texts and practices seen here.

Conceptually, royal accession and the acquiring of a new house were related; the Akkadian word *bītum* ("house") and its cognates (including Ugaritic *bt*) connoted both the physical structure one inhabited and the rulership one occupied (Tugendhaft 2012: 190). The kind of house one has is directly tied to how one relates to the land and intends to live on it. It seems to follow logically, too, that what kind of house a ruler had was tied to what kind of relationship to the land a ruler planned to develop and employ, or indeed would be able to prepare for and

[29] This is the basis of much of of practice and performance theories: Bourdieu and Nice 1977; Turner and Schechner 1988; Morris 1995; Lave and Wenger 1998, to name a few.

implement. The moral subtext of the Baal story is instructive in this regard. When Anat and Athtirat beg at El's tent for his intervention in resurrecting Baal and granting him his great stone palace, it is a necessary part of Baal's becoming a just ruler in relation to other rulers and to the broader land he hopes to rule over. Baal is only welcomed as a brother by the other ruling gods once he has his palace and can host a feast in it, but all the ruling gods (regardless of what their own home is like) depend on and regularly pay tribute to maintaining El and his tent by the water. The new can only proceed with respect for the old; the stationary and monumental is only stable if the farther-reaching parts of the territory and older, more mobile occupants of the land support it.

That the expansion of and aggregation around the EBA settlements at Sidon and TFK relied on the support and maintenance of a population that was at least partially mobile and actively maintained the techniques, knowledge, and skills of the past as part of their long-term land use strategy is supported by the evidence presented here. The phytolith and ground stone evidence, in the context of the larger settlement patterns revealed by excavations and climate patterns indicated by previous research, reveals practices that stored within them a range of possible ways of living in relation to the land. Cyclical exploitation of wetland, woodland, and grassland (agricultural) zones built adaptability into the landscape so that in times of stress, change in subsistence techniques and settlement organization was already infrastructurally and technologically available, and socio-culturally familiar and accessible. Increases in staple crop expansion were certainly undertaken during the EBII and EBIII, but they relied on a technologies of crop storage that were based in wetland resources and required the maintenance of those eco-zones, as well. Grinding tools whose use wear patterns suggest cereal/pulse processing were curated and reused over time with care, and fragments that could be used for this process were an essential part of a toolkit that allowed populations to maintain their processing techniques on the settlement or take them with them at times of necessary dispersal. Attention was directed in all these cases far more to developing a relationship to tools, plants, and place that was adaptive and flexible, rather than increasingly efficient and profitable in the short-term.

By maintaining this balance, we can imagine that in times of stress, authority was not necessarily threatened by a loss of central place (the metaphorical palace/palatial settlement of Baal) because that authority can also be found stored in the landscape and in the mechanisms for adaptation that are already are kept there (the metaphorical tent of El). Brotherhood – the ability to retain proper alliances of kinship and their metaphorical political equaivalents – was preserved through the ability to sustain lifeways through crises, not to avoid crises altogether. After all, with gods like Baal around controlling the weather, avoiding crises was not a viable long-term strategy to depend on.

6.2 *On earth as it is in heaven*

The conceptual link between the actions of the gods, the earth, and the fate of humans weaves it's way throughout the stories and verses presented here. What the gods do of course affects the earth, the weather, and the lives of humans, but their response can mitigate those consequences. This is echoed in the incantation tablets from Ebla:

In heaven a wind arose,

On earth dust swirled;

A south wind rose,

A north wind rose,

And a dust storm arose;

The body of a man arose.

- Ebla incantation Tablet MRAH O.1920 (Veldhuis 2006)

This has both literal and evocative metaphorical connotations. Changing wind patterns affect the seas, the storms, the weather, and the rise or fall of human life. If these winds start in heaven among the actions of the gods, then there is a direct relationship that must be maintained to sustain that balance in the hope of good winds, while preparing for volatile ones. As we have seen in previous chapters, Baal's actions can cause drought or storm, and his siblings can raise winds of vengeance. Importantly, this will come in cycles over time, the good followed by the bad, but it can always be put back into balance. This is the predictability of unpredictability in the climate patterns of the Middle Holocene – it will always change, but there are better and worse strategies for being ready for change.

The early aggregated settlements of the Southern Levant and Western Greater Mesopotamia seem to have attempted to rely on increasing surplus agriculture and having enough grain in storage to weather the weather without having to change their socio-political organizational systems, which ultimately failed (Rosen 2007). The small-scale nature and fluctuations in size and occupation density in the contemporary settlements in EBA Lebanon have often been deemed to never have really gotten going enough to be considered as collapsed; they are rather failures to ever be properly complex (Bell and Jayne 2006).

The evidence presented here, however, suggests a different perspective. Change, in terms of cycling between resource zones and preparing for more mobile or stationary ways of supporting the community as a continuous process, was built into the socio-political organization itself. This, then, would predispose the population to accept organizational and subsistence adaptations during times of drought, or flood, or other stresses, because that adaptability was already a feature of their lives. To be able to disperse and to be able to remain small-scale and yet participate in larger scale agricultural and trade ventures was its own kind of success. The gods may destroy the fields with their fights and whims every seven years, metaphorically or literally, but there are always the wetlands, pastoralism, and other ways of living in a place until the winds change again.

6.3 Looking back, thinking forward

Thinking of resilience and landscape storage in the terms presented in this study has promise for engaging more critically with our own society's increasingly urgent confrontation with over-expansion and climate change. The societies of EBA Lebanon were previously often viewed as failures to become properly complex in the ways and at the rate of their neighbors – but their resilience over time should in fact be a lesson in preserving multiple ways to live in relation to changing land and climate. We must to think not only about what technological strategies are more sustainable, but about the ways in which society can culturally come to accept adaptation to personal lifeways. It is not enough to have the technologies, skills and means to survive the stresses of a climactically and politically volatile world; we must also engage the social will to build those into our daily lives in a material and conceptual way.

The relationships of EBA societies in Lebanon to their tools and their land as presented here suggest we keep a close eye on past ways of knowing as we explore options for the future. They also suggest that we keep in mind that our ways of living every day are not separate from our larger relationships to appropriate leadership (policy, perhaps, would be the modern equivalent) and land use. The connection between body, house, and land is echoed across millennia by the twentieth century Lebanese poet, perhaps the most famous poet from Lebanon, in perhaps his most famous poem:

> *Build of your imaginings a bower in the wilderness ere you build a house within the city walls.*
> *For even as you have home-comings in your twilight, so has the wanderer in you, the ever distant and alone.*
> *Your house is your larger body.*
> *It grows in the sun and sleeps in the stillness of the night; and it is not dreamless. Does not your house dream? and dreaming, leave the city for grove or hill-top?*
> *[…]*
> *In their fear your forefathers gathered you too near together. And that fear shall endure a little longer. A little longer shall your city walls separate your hearths from your fields.*
>
> \- Khalil Gibran, "On Houses," *The Prophet,* 1923

Gibran offers the image of clustering together in cities as a symptom of fear, distress, and social regression (in his context, caused by the war, but applicable to a range of human-induced stressors) rather than an attribute of progress and positive community growth. The ability to move one's body and one's house throughout the land is the dream of resilience and recovery he advocates here, which has strong resonances with El's tent by the water in the ancient texts discussed above.

Perhaps there is a lesson for researchers, too, in this. I suggest that instead of focusing research attention on the failure of past societies to gather in the right way, or framing their dispersal in terms of an inability to maintain their levels of social, political, and technological complexity, we should take the resilience of small-scale settlements over time as a lesson in preserving multiple ways to live in relation to changing land and climate as we confront our own societies' impulse to increasingly expand even as our environment struggles and our climate flails. This is the way forward, guided by the past.

Figures

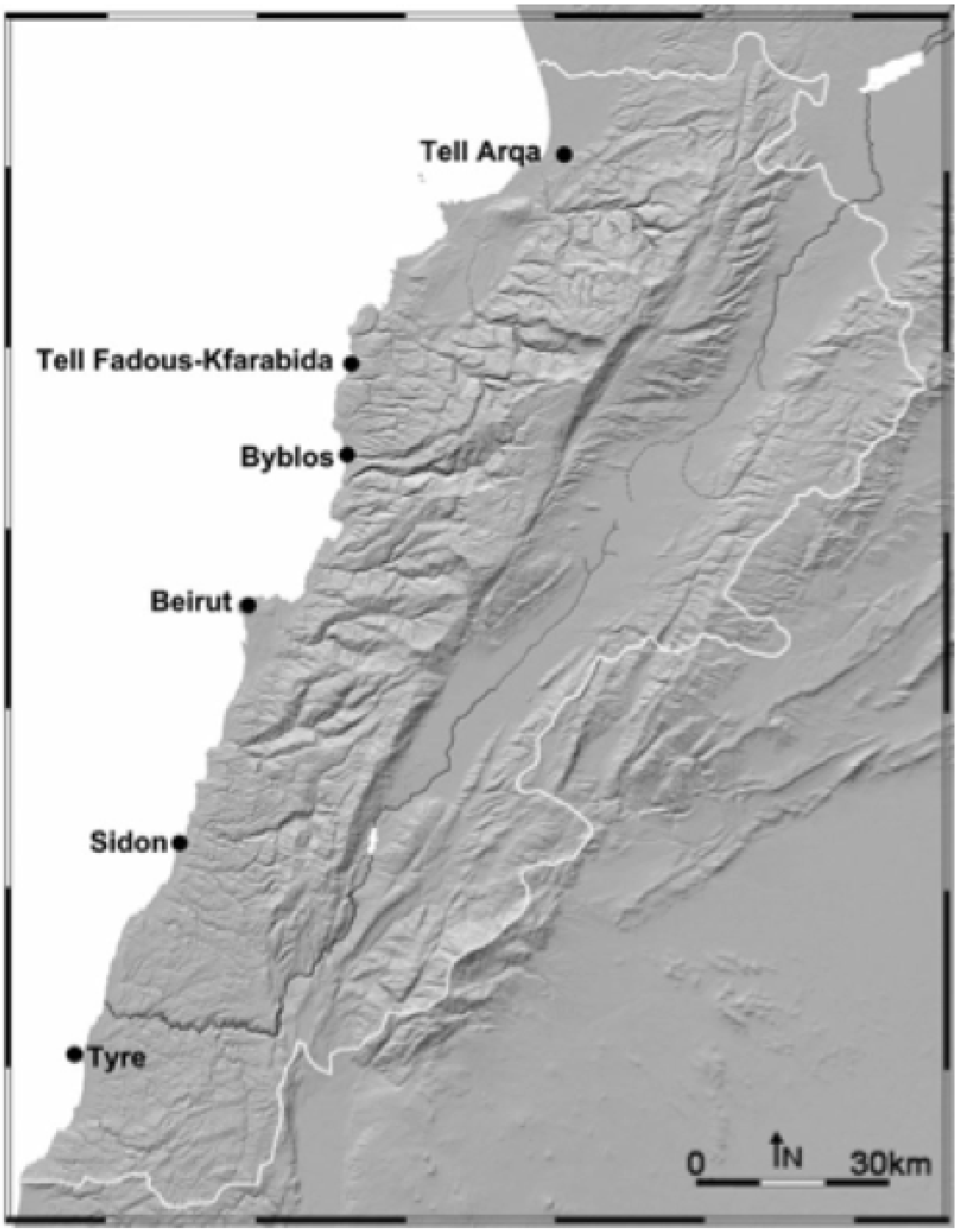


Figure 13.1: Topographical map showing the two case study sites, Tell Fadous-Kfarabida and Sidon, in relation to other coastal EBA sites within the boundaries of modern Lebanon. Image credit: Dr. Hermann Genz, AUB.

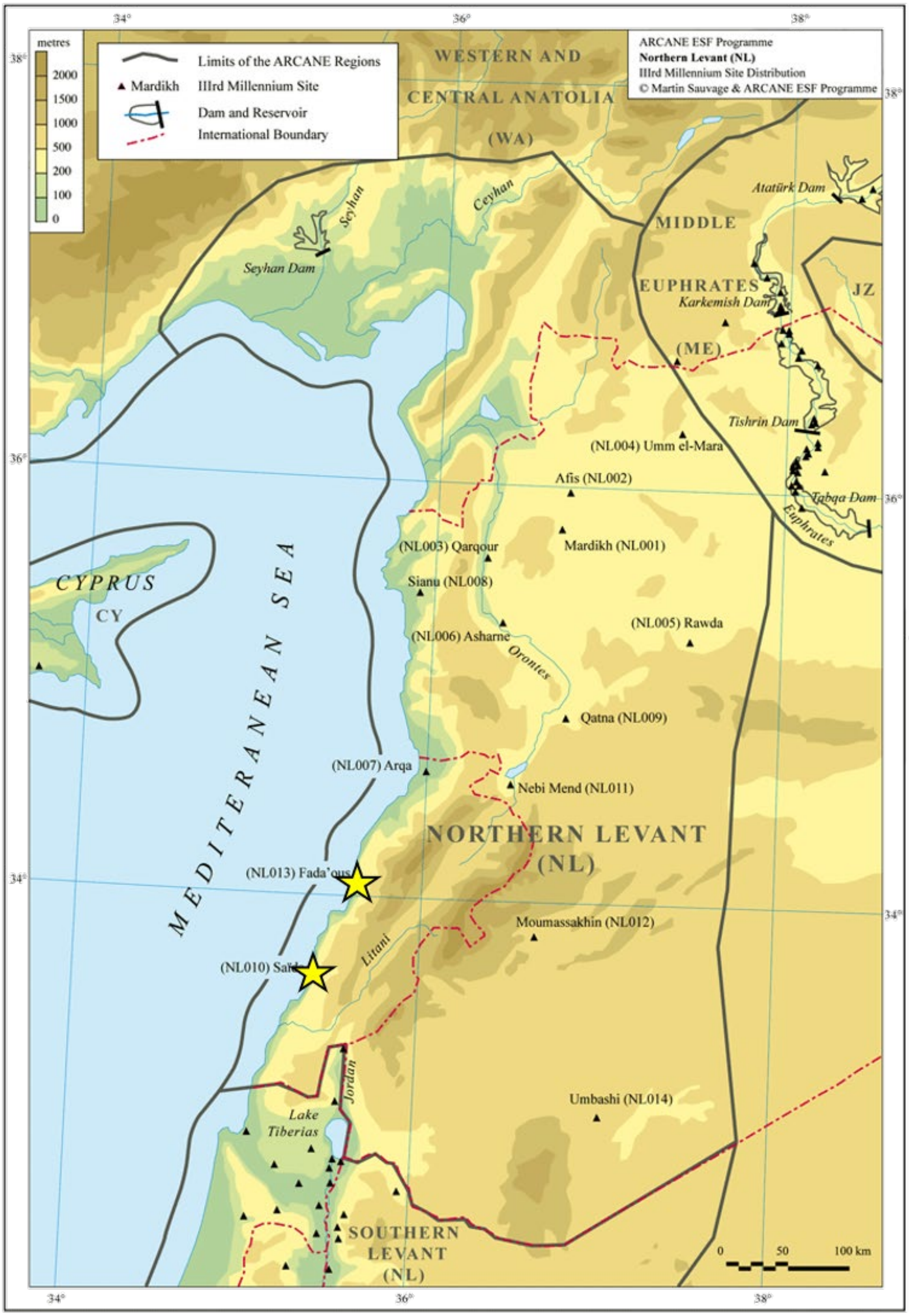


Figure 1.14: The case study sites, TFK and Sidon, within the greater Eastern Mediterranean and Northern Levant. This map, from the ARCAANE project that is documenting third millennium chronologies in this region, shows the limited availability of sites from Lebanon in relation to neighboring regions. Image credit: ARCAANE Project (www.arcane.uni-tuebingen.de).

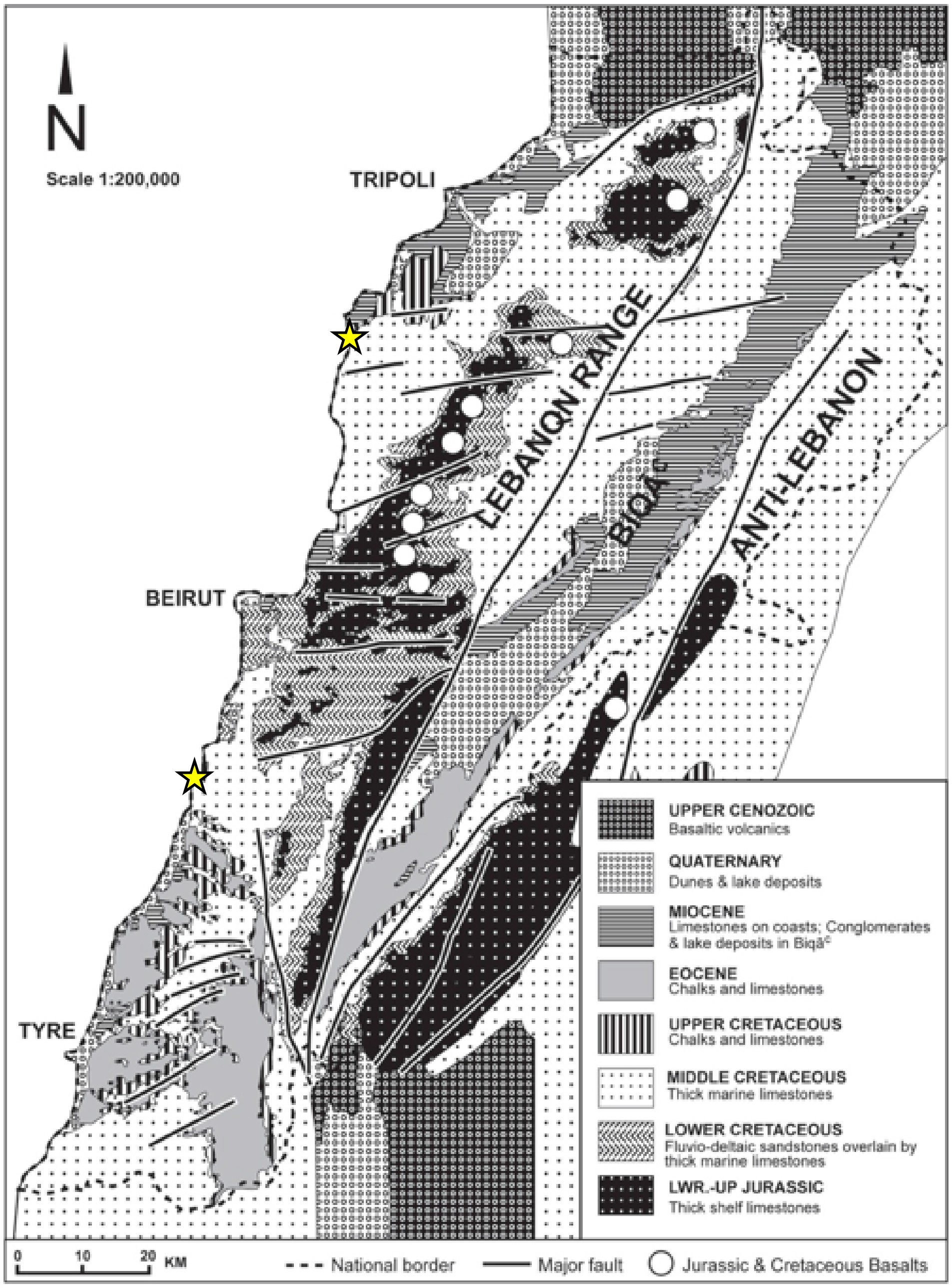


Figure 1.15: Geological map of Lebanon showing the extreme and restricted nature of the local geomorphology, including the Lebanon and Anti-Lebanon mountain ranges that rise almost directly from an extremely narrow coastal plain. Image credit: Al Mashriq Project (almashriq.hiof.no).

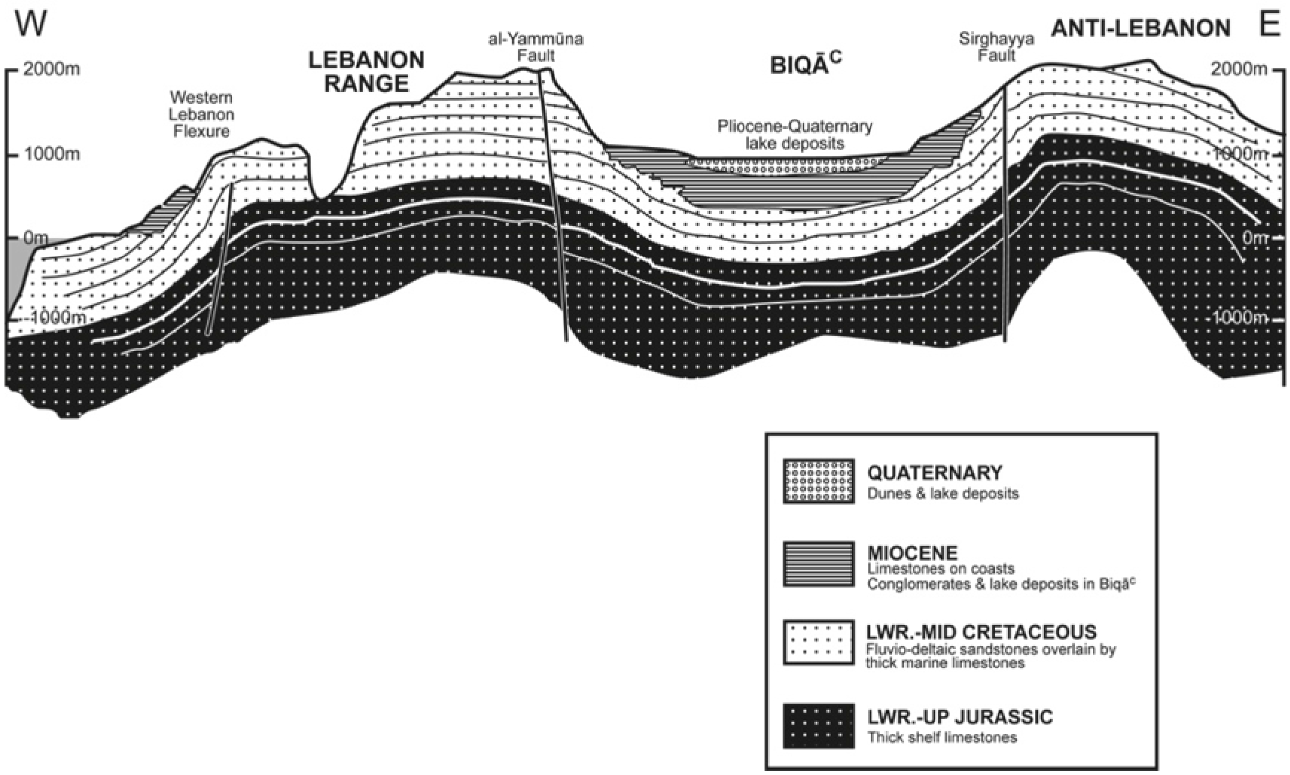


Figure 1.16: Schematic geological cross-section of Lebanon emphasizing the rapidly changing topography and the restricted coastal zone. Image credit: Al Mashriq Project (almashriq.hiof.no).

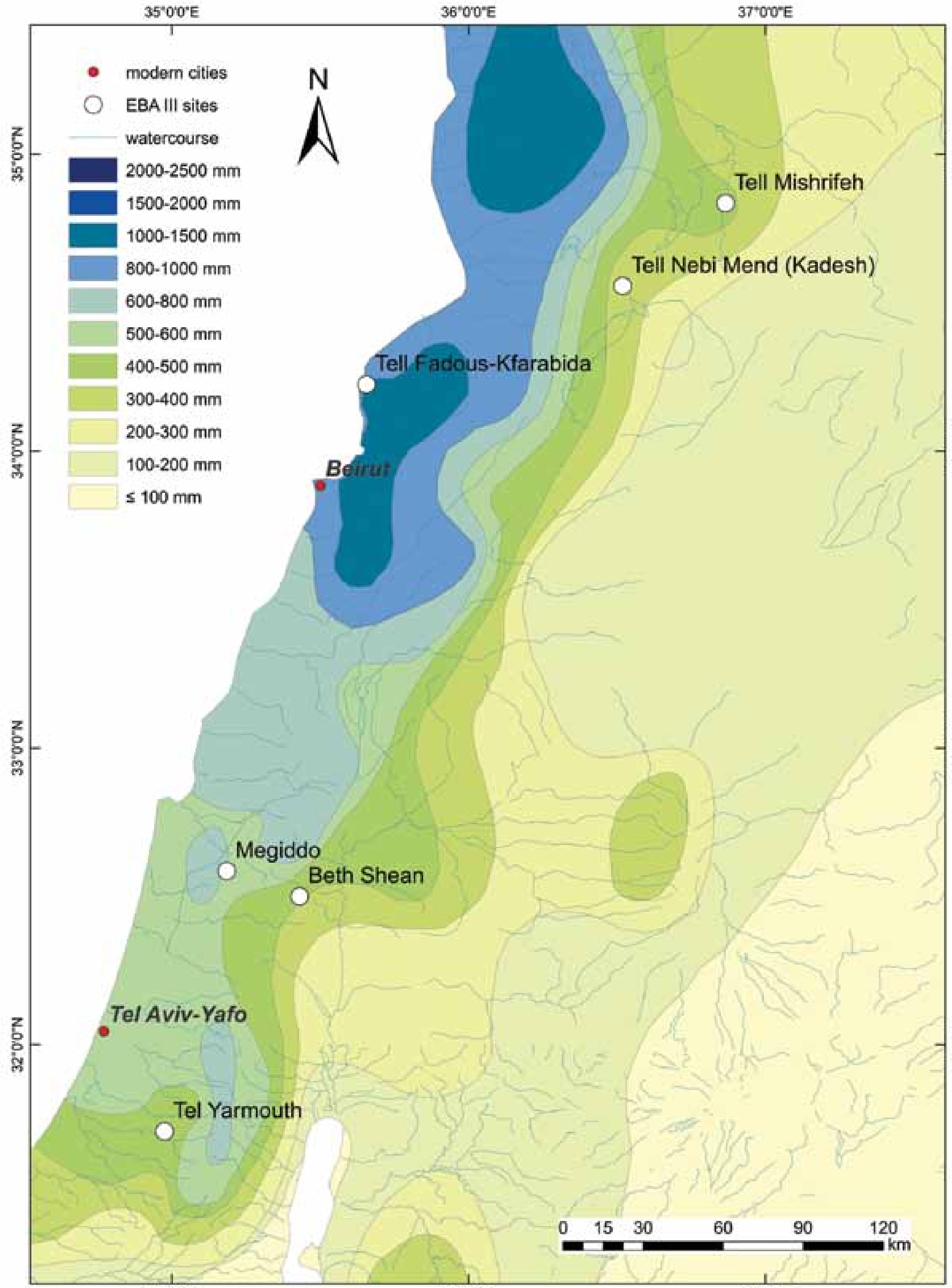


Figure 1.17: Watercourse and rainfall zones in Lebanon, showing the variability of water flow and access. Image Credit: Riehl et al 2014

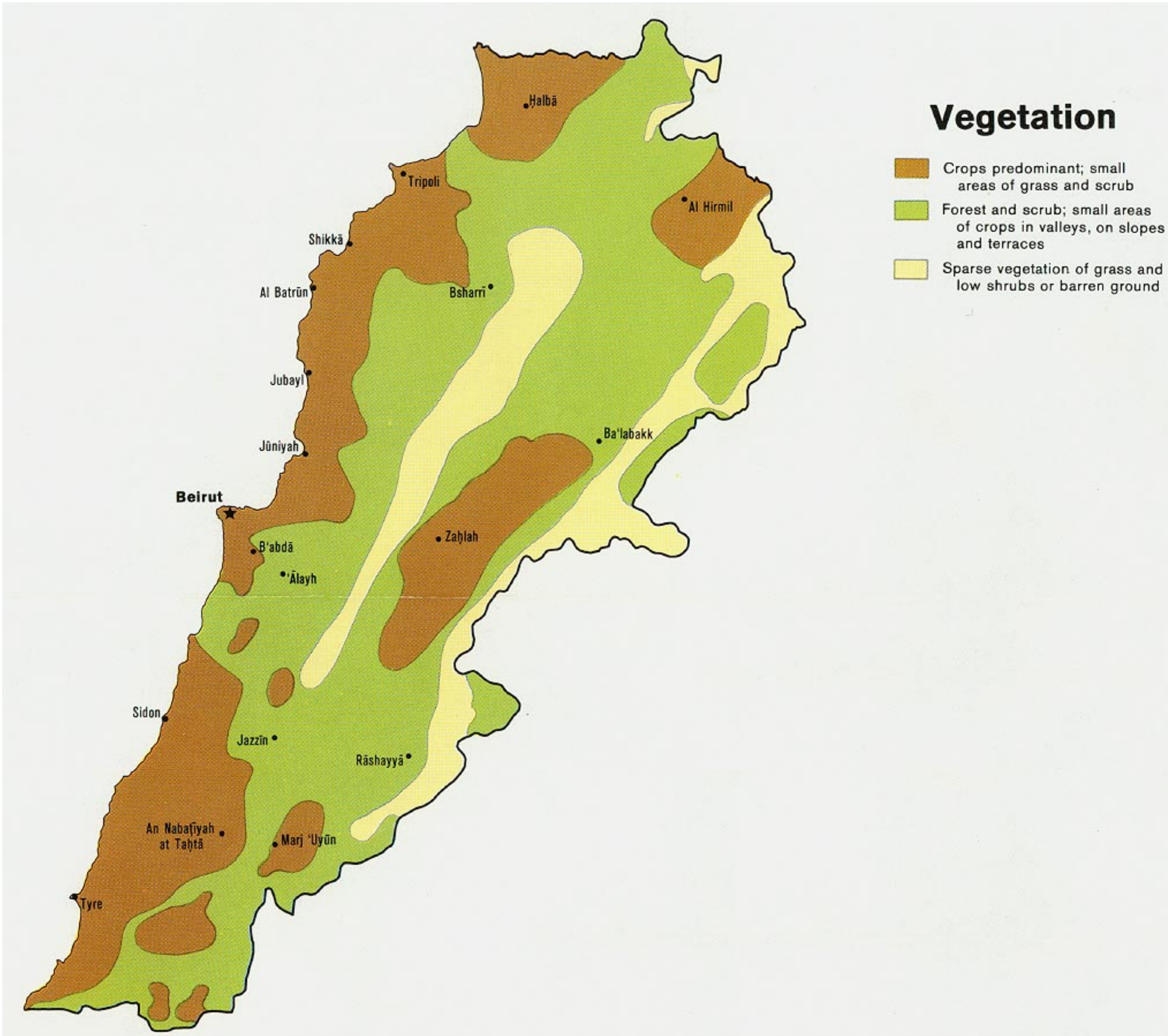


Figure 1.18: Modern general vegetation zones in Lebanon. Image credit: Al Mashriq Project (almashriq.hiof.no).

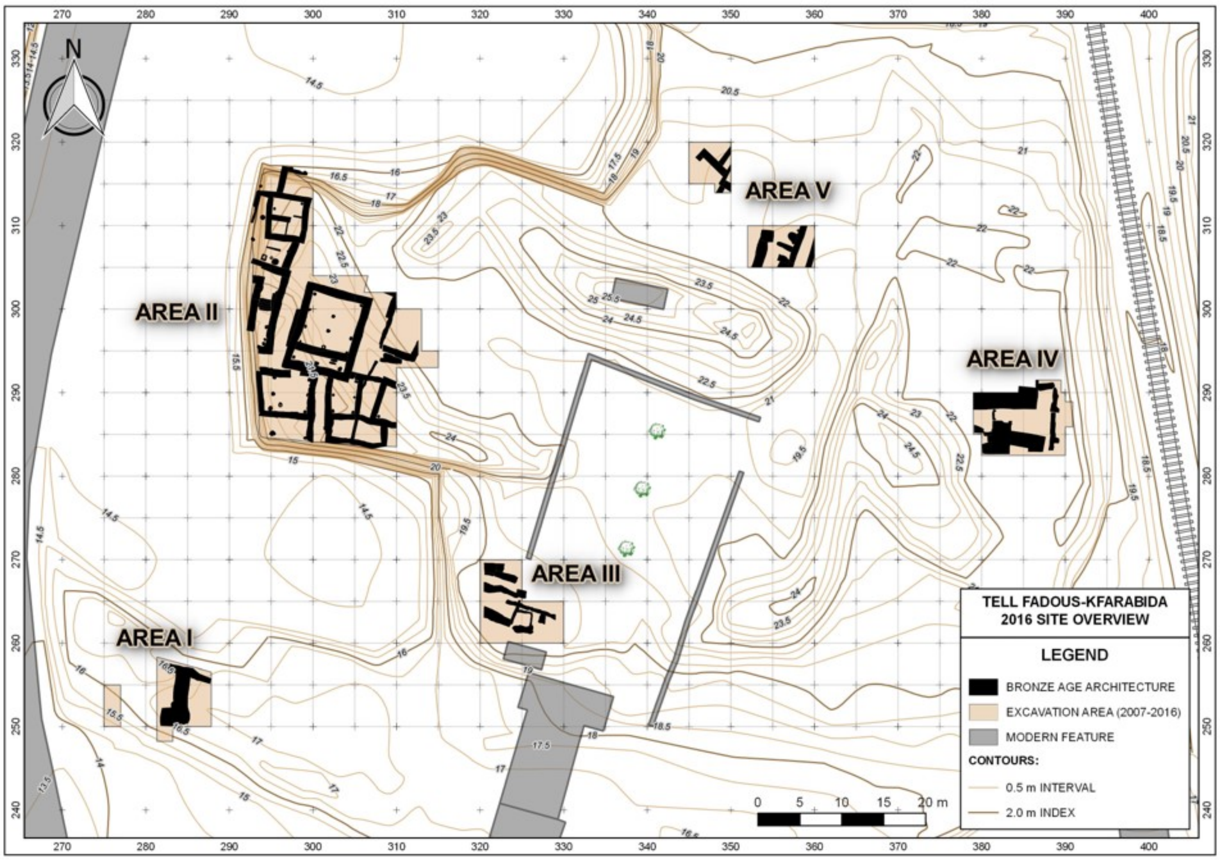


Figure 1.19: Schematic plan of Tell Fadous-Kfarabida after the 2016 excavation season, including all excavated areas. Image credit: TFK Project 2016

Figure 1.20: Photo of TFK looking south, showing the modern wadi path in front of the archaeological tell and the proximity of both the coast and the foothills. The exposed northern and western faces of the tell are the results of the bulldozing work prior to archaeological investigation of the site.

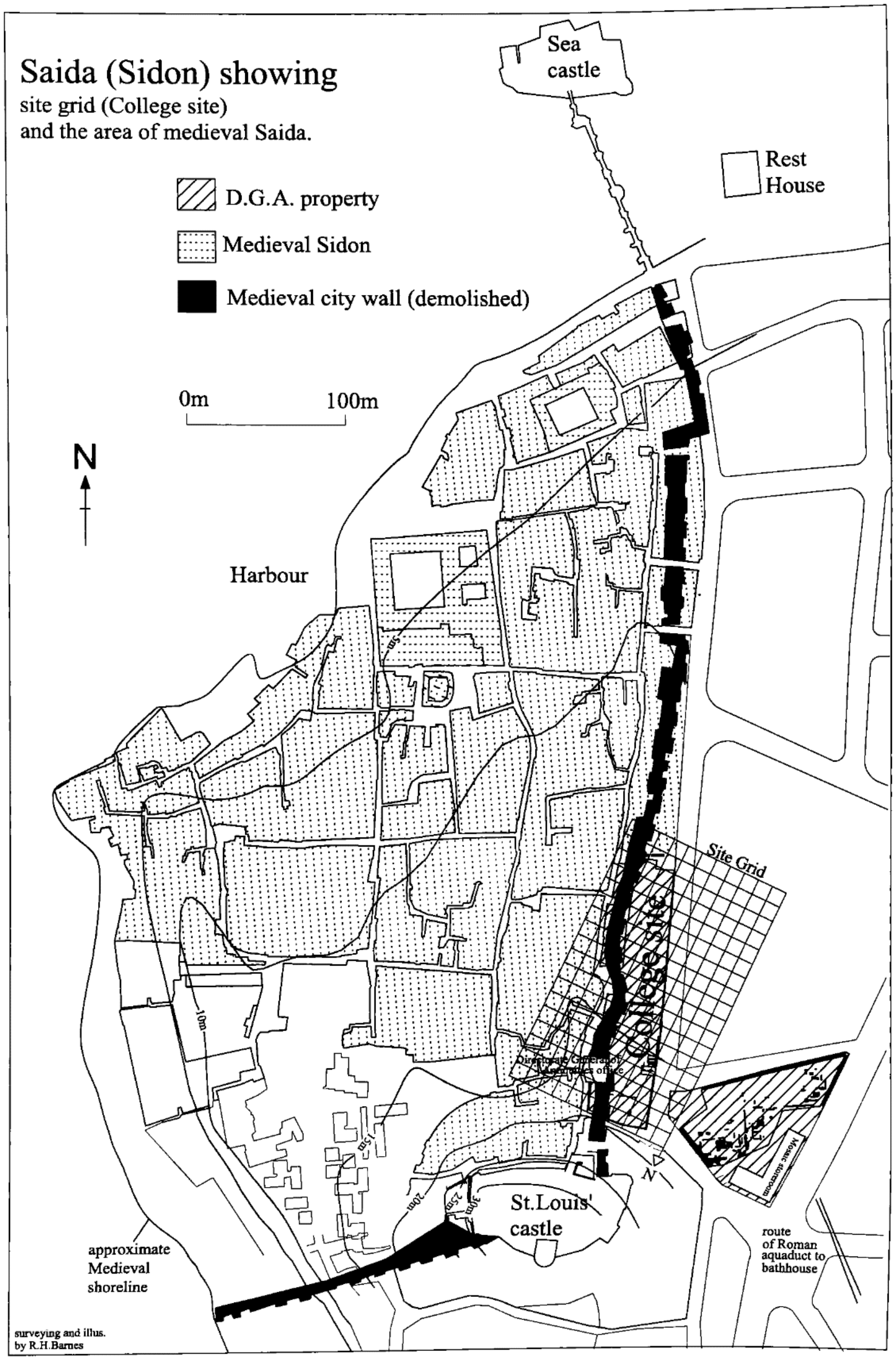


Figure 1.21: Schematic plan of the Sidon excavation areas in relation to the (still occupied) medieval town and modern roads. Image credit: sidonexcavation.com

Figure 1.22: Photo of the current excavations at the Sidon College Site, showing the medieval/modern city surrounding the site.

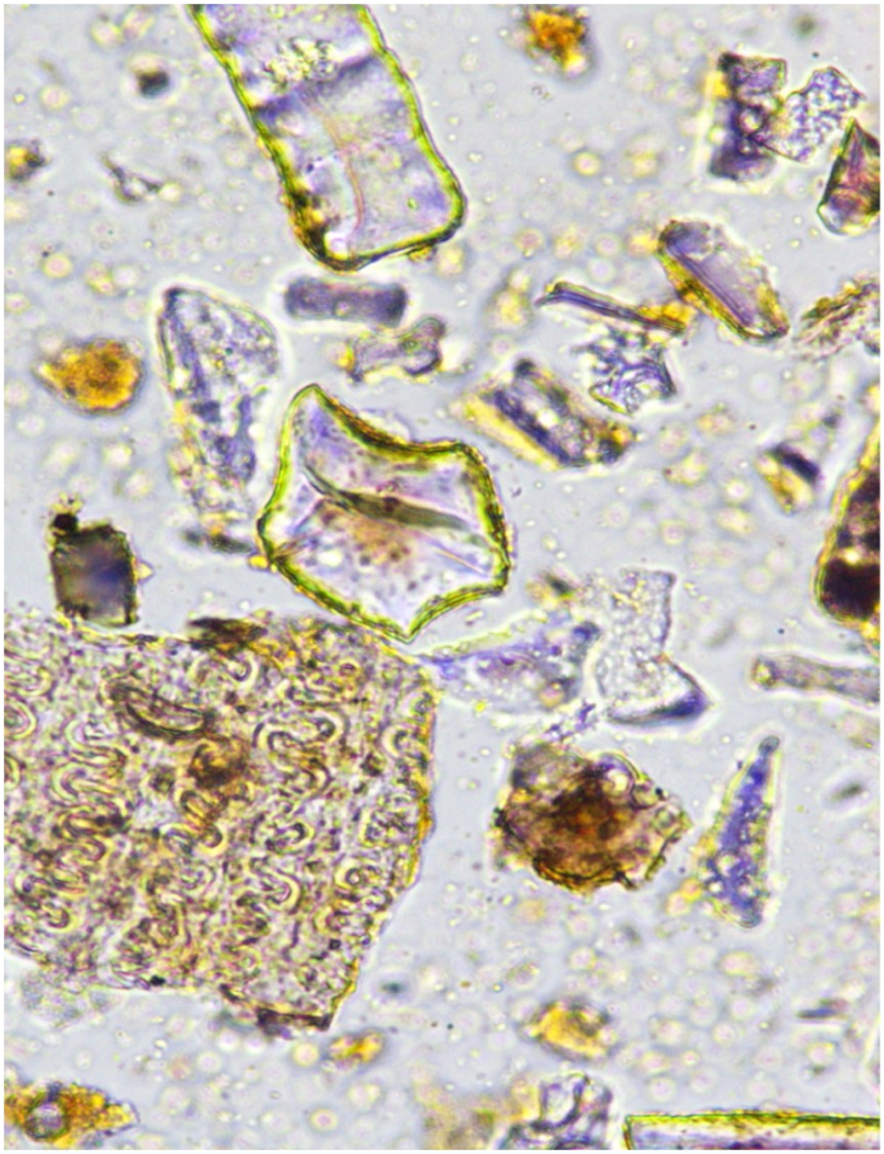


Figure 1.23: Examples of phytoliths from TFK.

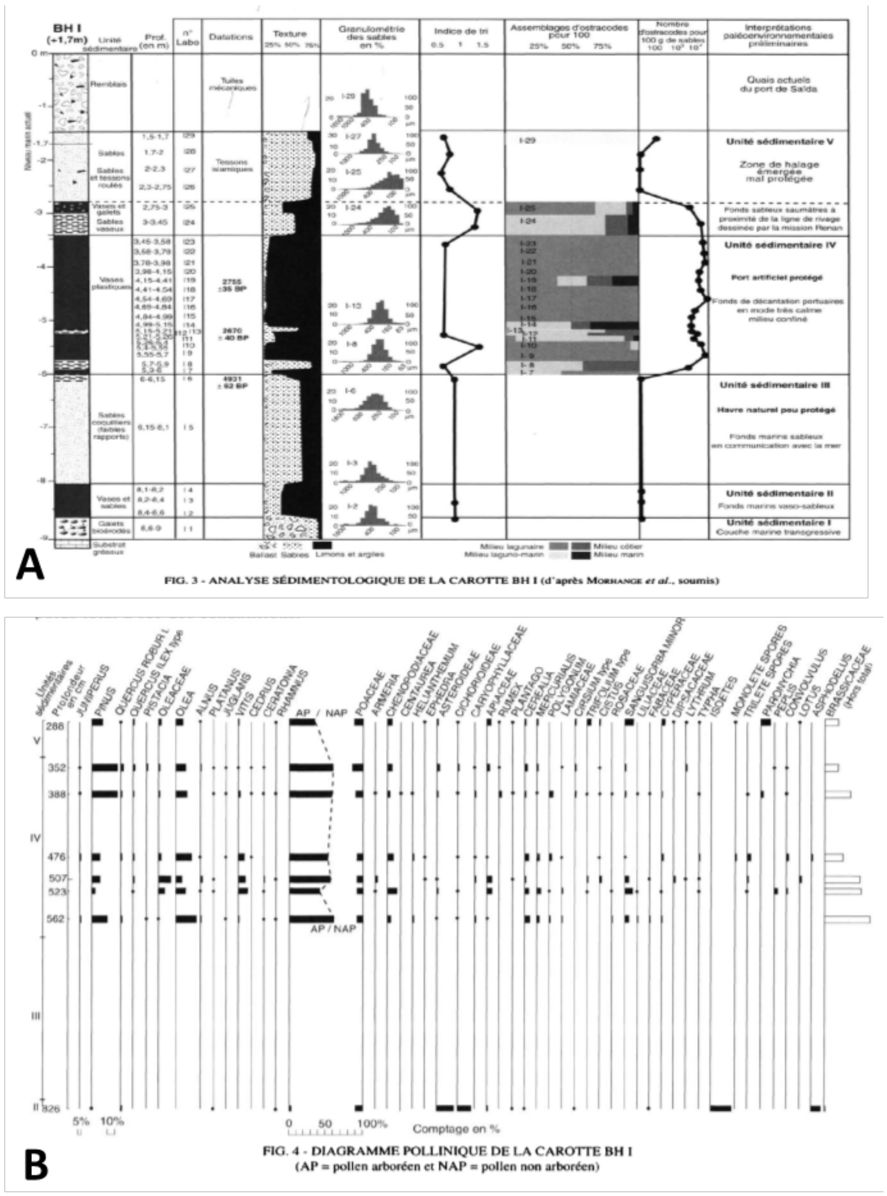


Figure 2.1: Sidon marine pollen core, sedimentary/chronological analysis (A) and pollen counts (B); Morhange et al 2012:93-94

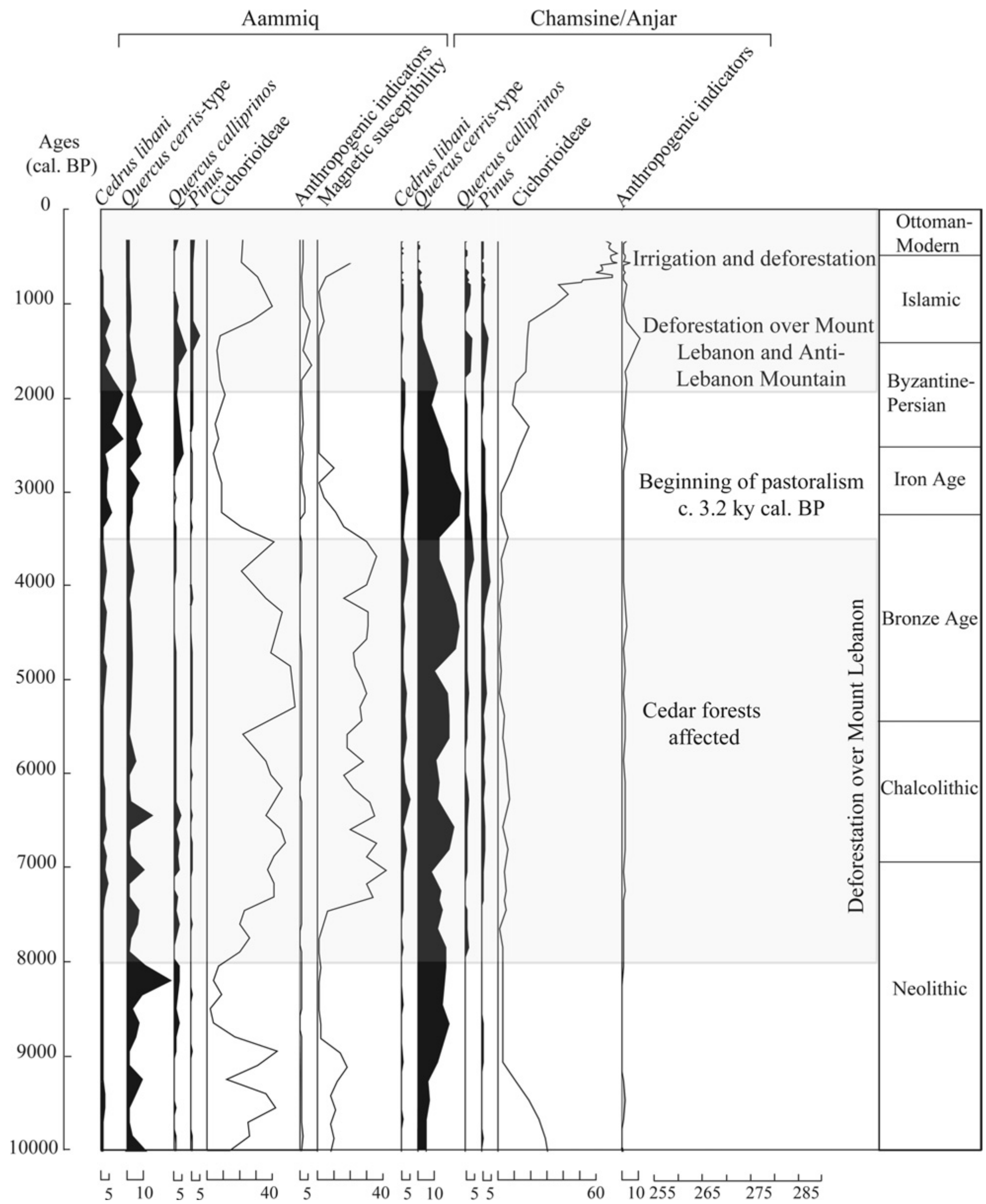


Figure 2.2: Arboreal pollen vs pollen from anthropogenic indicators at Ammiq and Chamsine, in the southern Biq'a, as identified by Hajar et al (2010: 752).

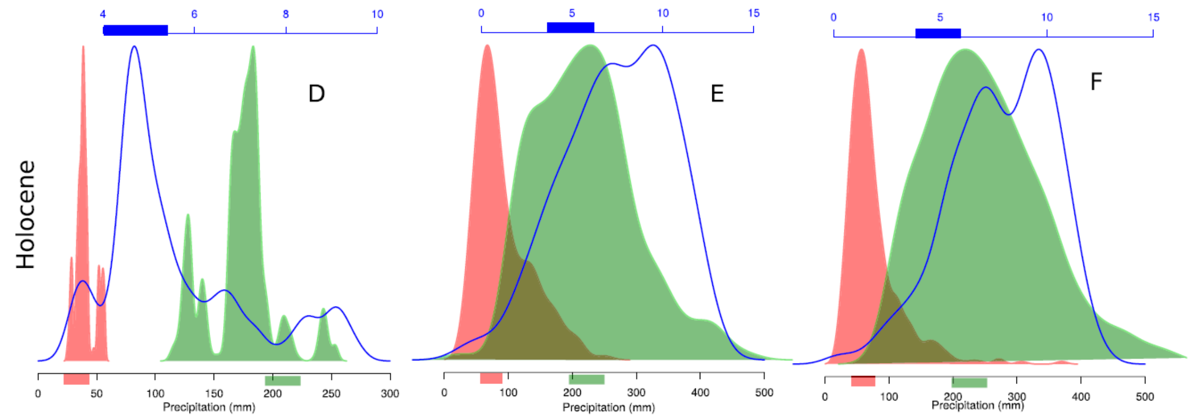


Fig. 6. Modern climate envelopes of six pollen taxa among those used for the past climate reconstruction: (A) Asphodelus; (B) Chenopodiaceae; (C) Artemisia; (D) Cedrus libani; (E) Quercus coccifera; (F) Olea europaea. Three taxa (A, B & C) are identified in the glacial samples, including the Younger dryas period. The three others are identified in different samples within the Holocene period. The small boxes indicate the range of each reconstructed climate variable (blue: Tjan; green and red: winter (NDJ) and summer (JJA) precipitation, respectively) during the YD (upper panel) and the Holocene (lower panel). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Figure 2.24: Ceddadi and Khater's (2016: 164) diagram for normalized Holocene dates and data from Ammiq and Chamsine, with Al Jourd added. Clear micro-regional differences in precipitation as well as plant taxa groups ("envelopes") are visible between the three Biq'a Valley zones. Late Pleistocene data has been excluded as it is not relevant for this study, but is presented in the original article as well.

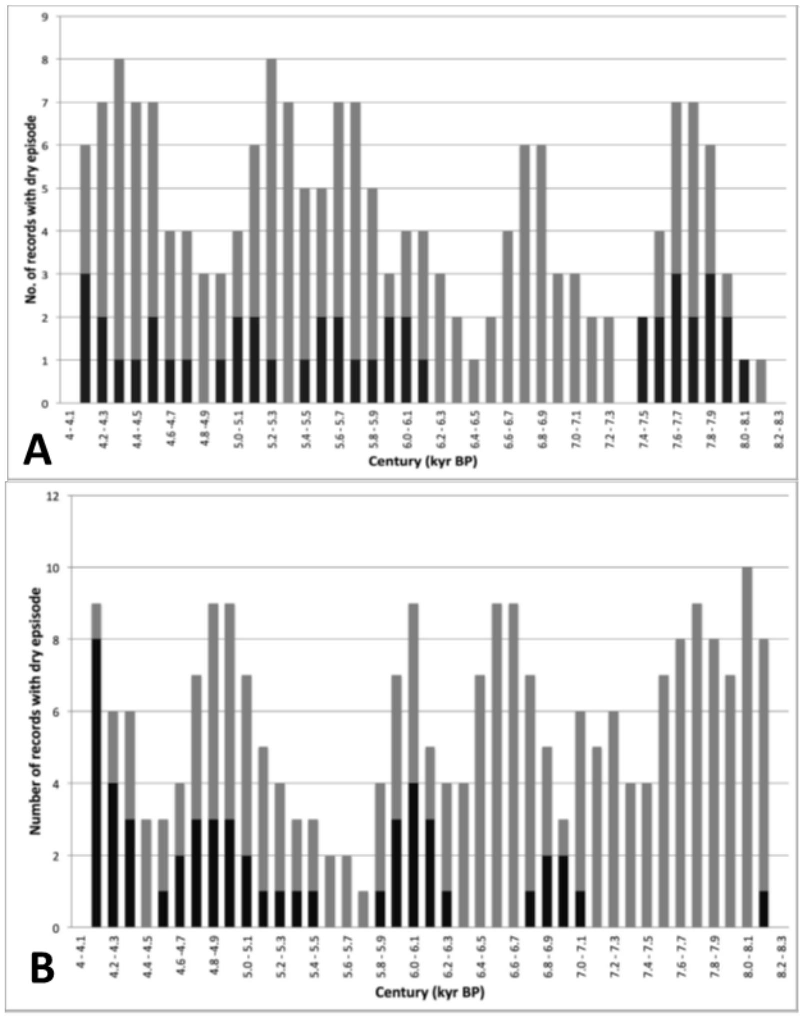


Figure 2.4: Clarke et al's (2012:106-108) diagrams for combined proxy data indicating precipitation highs and lows. Note the opposite high/low patterns for the Southern Levant/Cyprus (A) and the more mountainous Anatolia (B), showing how the same climate factors can manifest in very different extremes in different geographies.

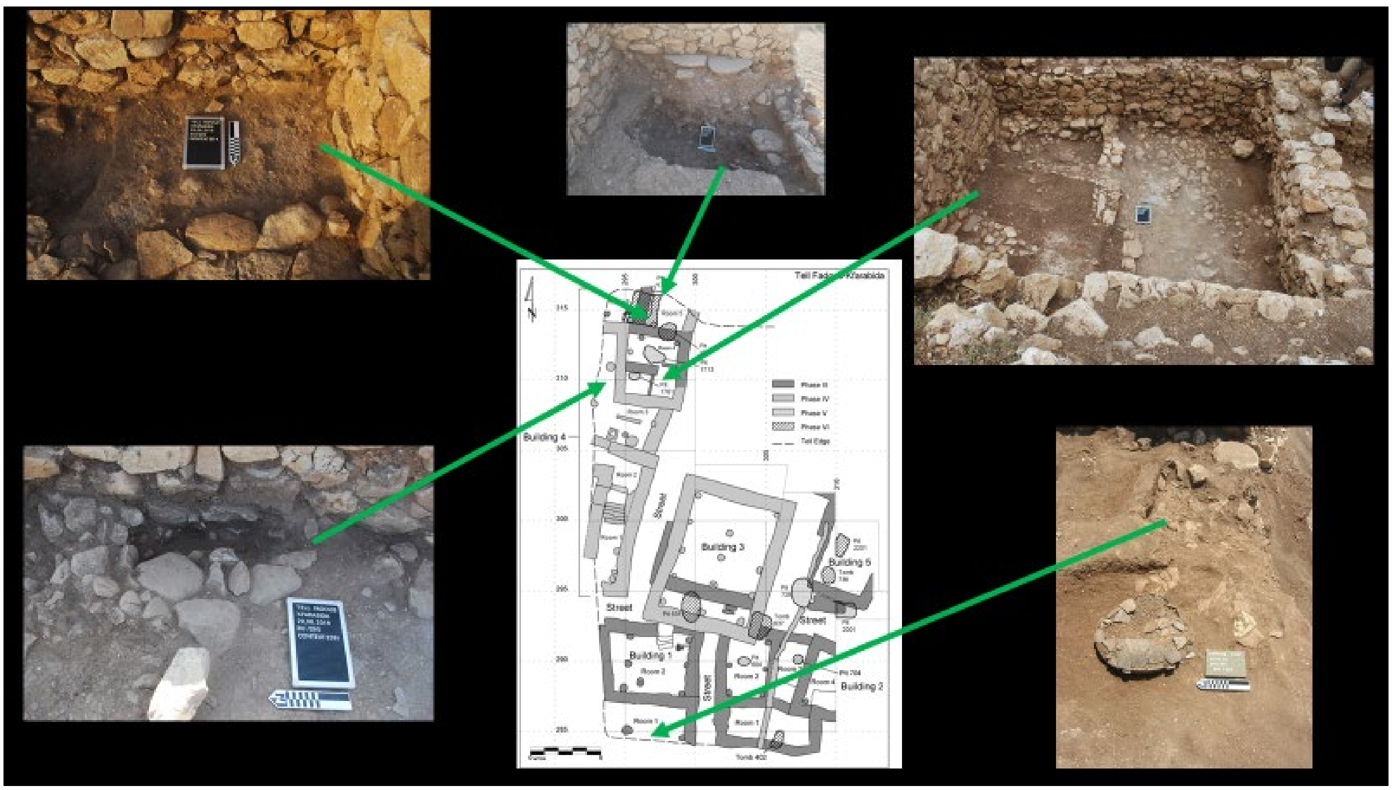


Figure 4.1: Examples of storage compartments and their locations in Area II (main tell area) of TFK.

Figure 4.2: Rectilinear, partially stone-lined storage compartments in the basement of Building 4, Room 4.

Figure 4.3: Partially stone-lined pit next to economic/domestic labor installations in Room 3, Building 4, at TFK.

Figure 4.4: Cross-sectioned rectangular storage compartment, partially stone-lined, along the southern wall of Room 5, Building 4, at TFK

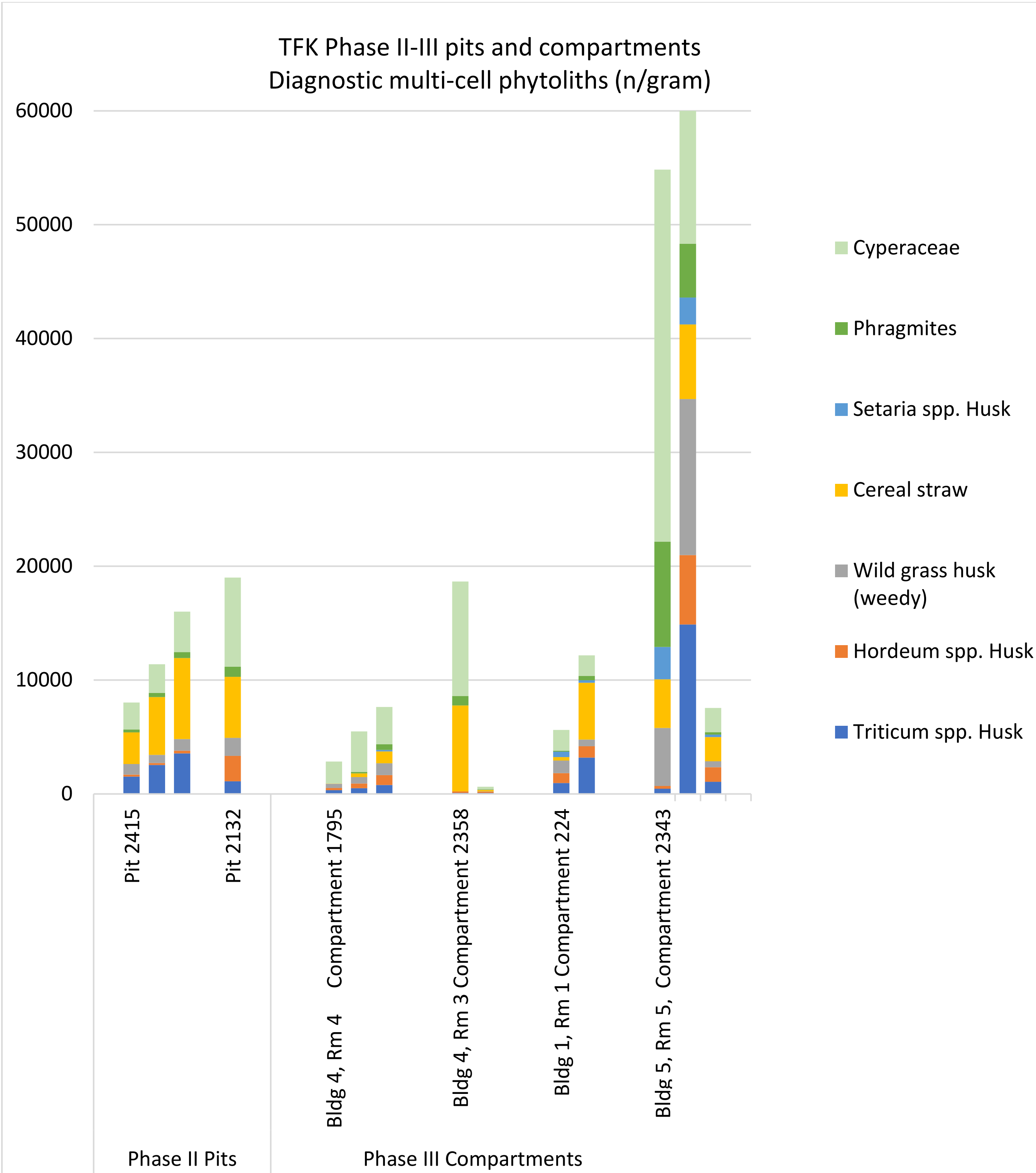


Figure 4.5: Densities (n/gram count) of all multi-cell diagnostic phytoliths for all Phase II-III pits and compartments at TFK.

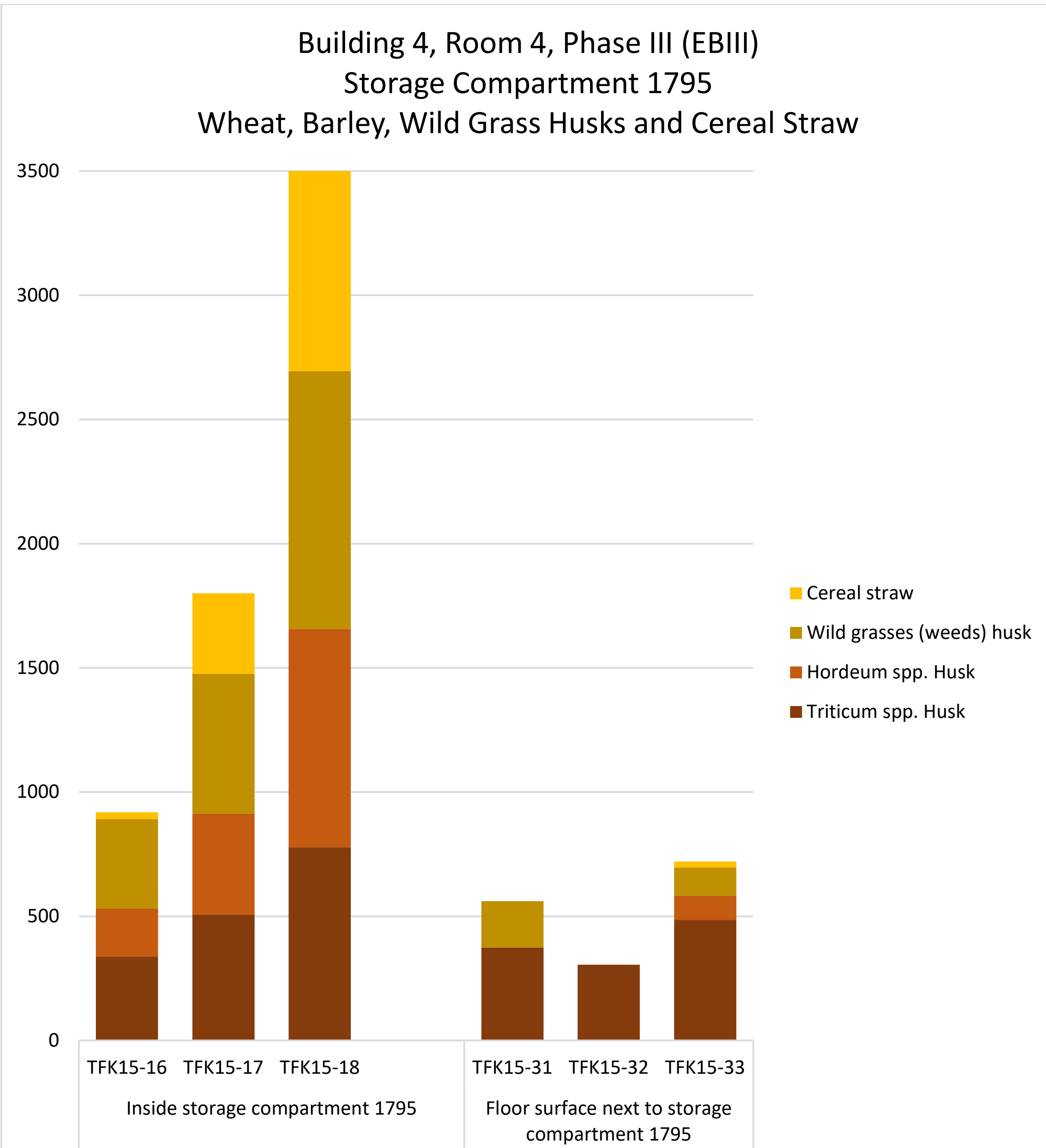


Figure 4.6: Multi-cell grass husks from storage compartment 1795 and the floor directly adjacent to this compartment.

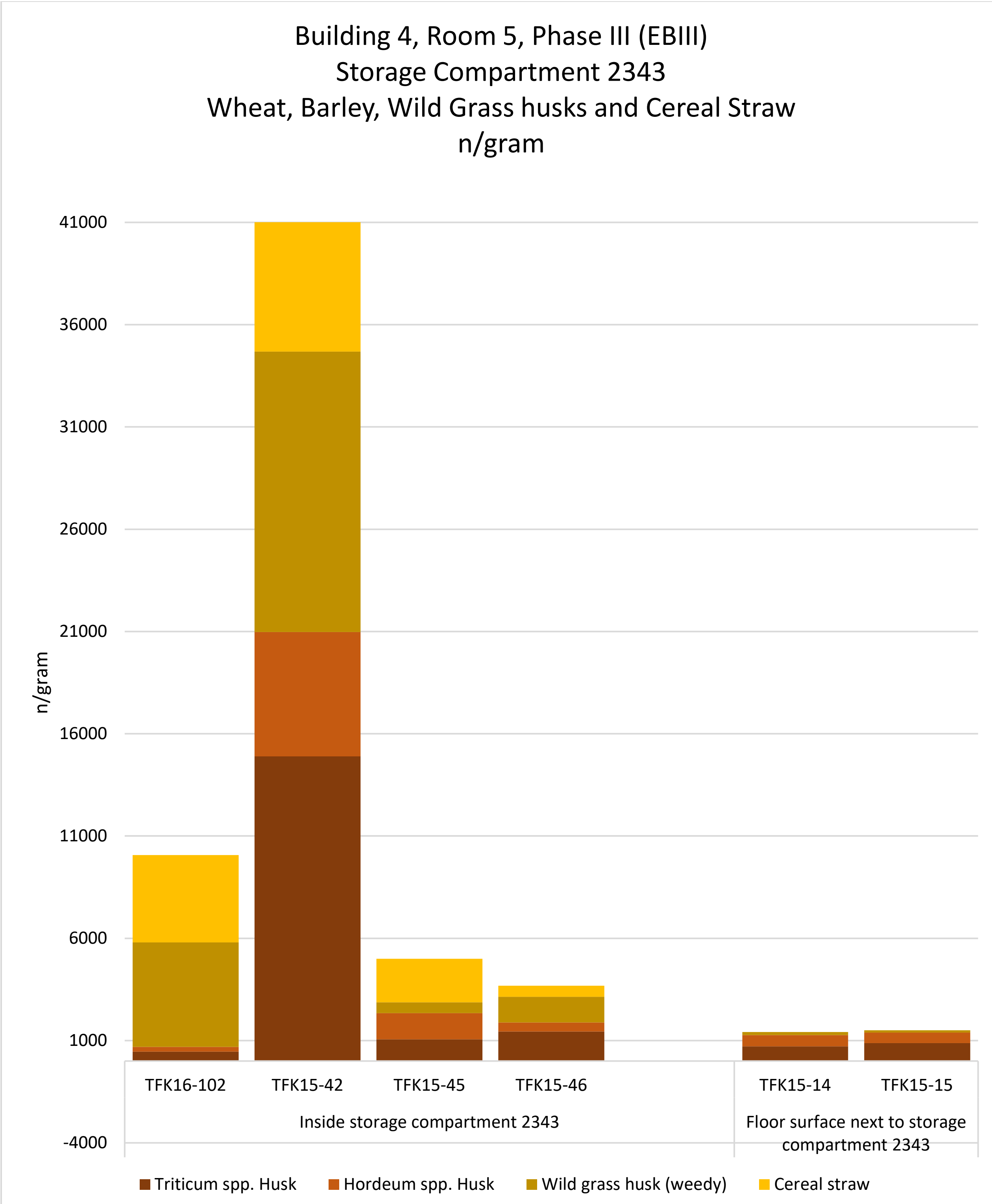


Figure 4.7: Multi-cell grass husk phytoliths for storage compartment 2343 and the floor surface adjacent to the compartment

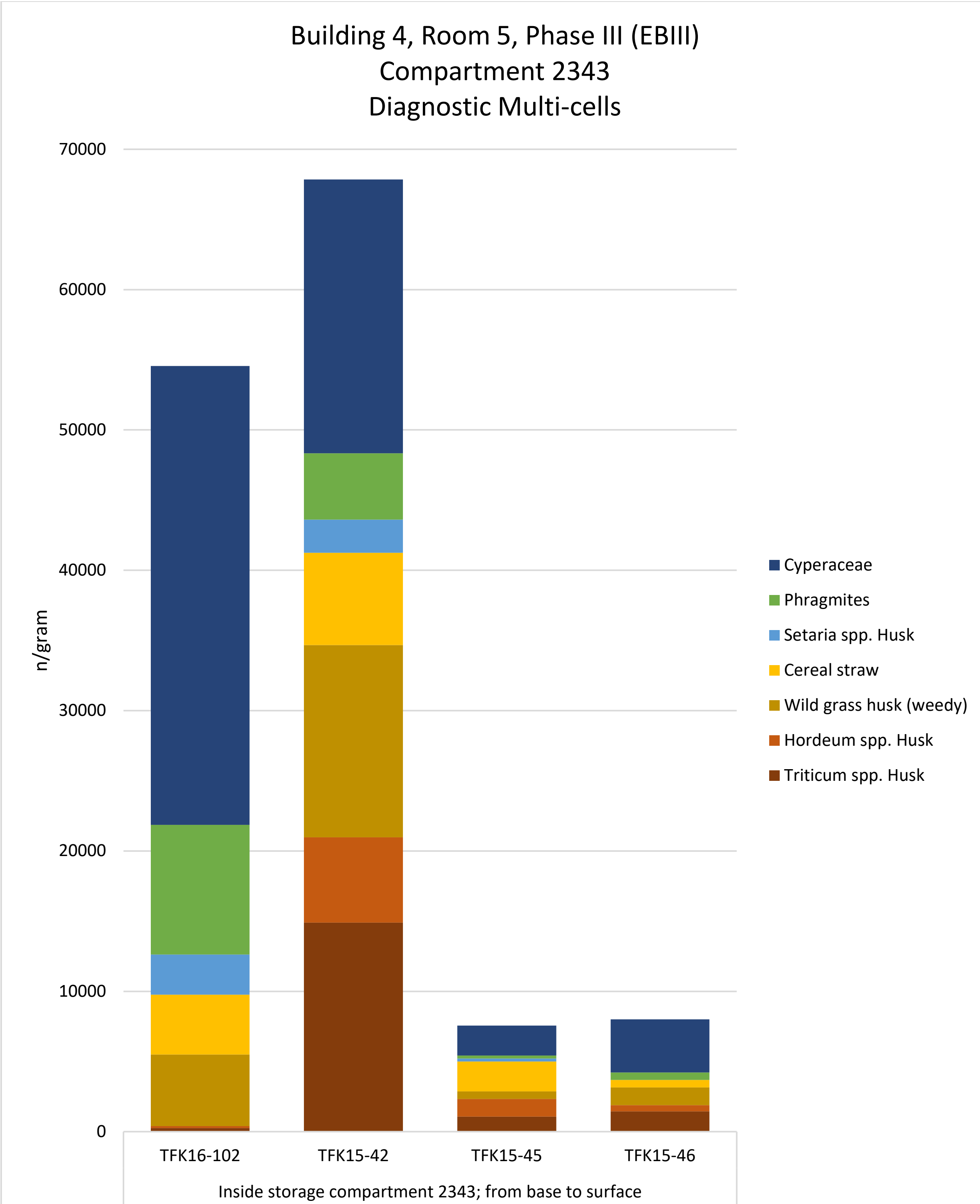


Figure 4.8: TFK EBA Storage compartment 2343, all diagnostic multi-cell phytoliths from base to surface.

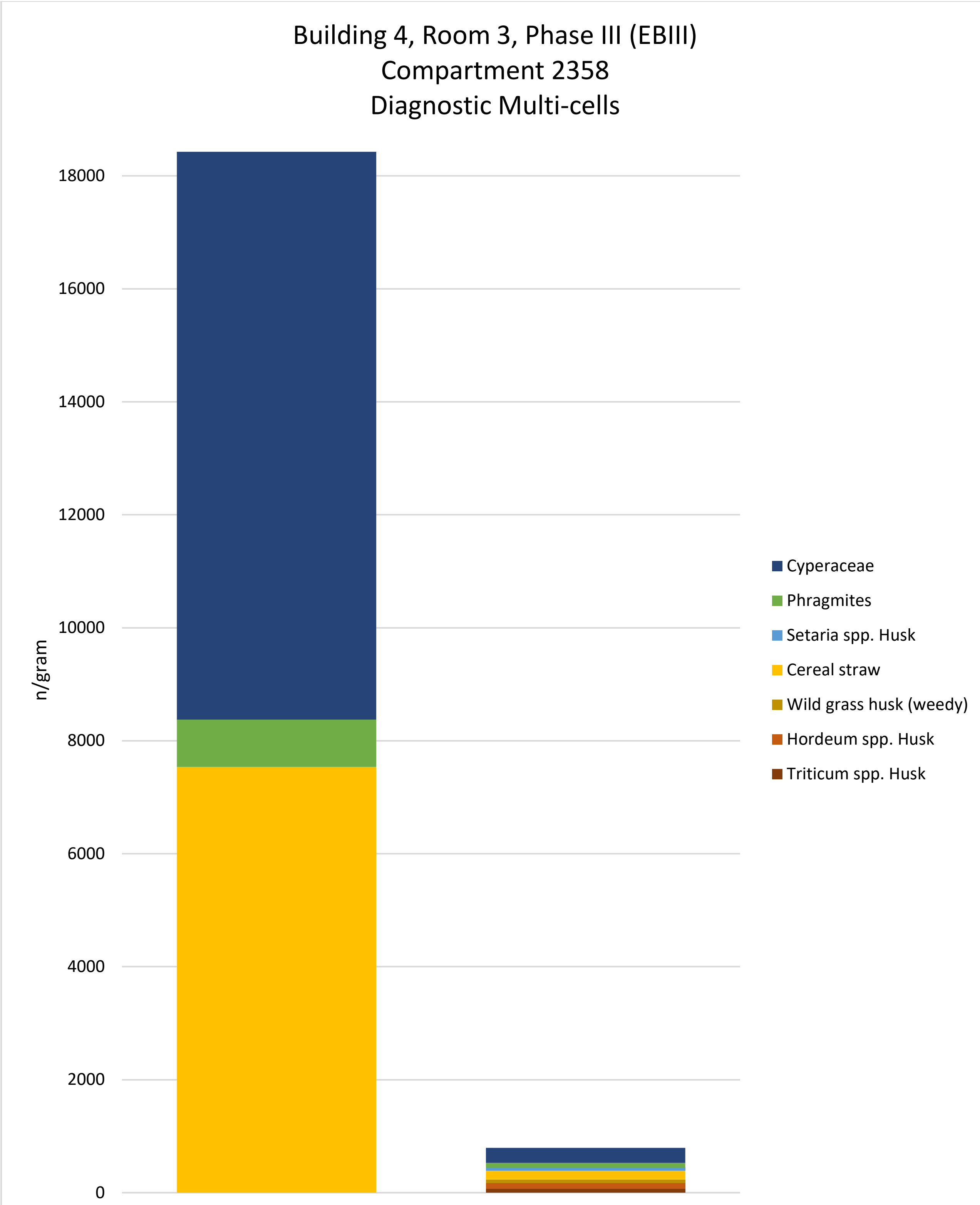


Figure 4.9: TFK Phase III storage compartment 2358, all diagnostic multi-cell phytoliths. The first column shows the sample taken at the base of the compartment, described as "white, powdery degraded plaster" and the column on the right shows the sample taken towards the middle of the compartment.

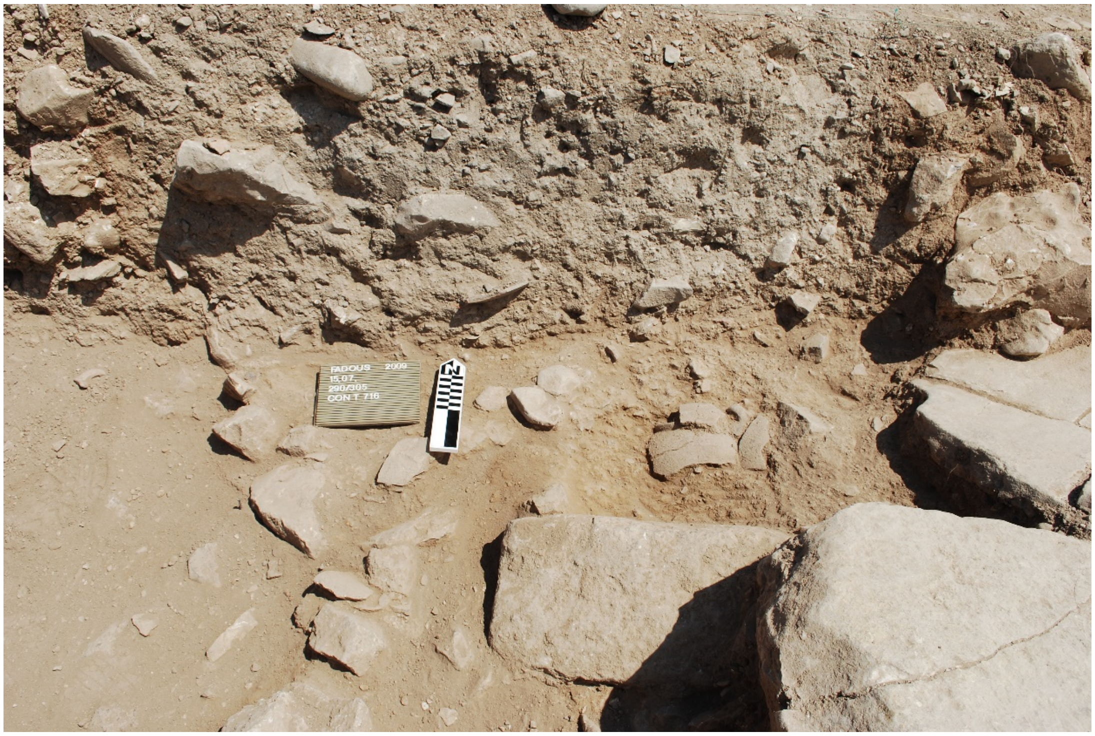


Figure 4.10: Cross-section of EBIV Pit 719

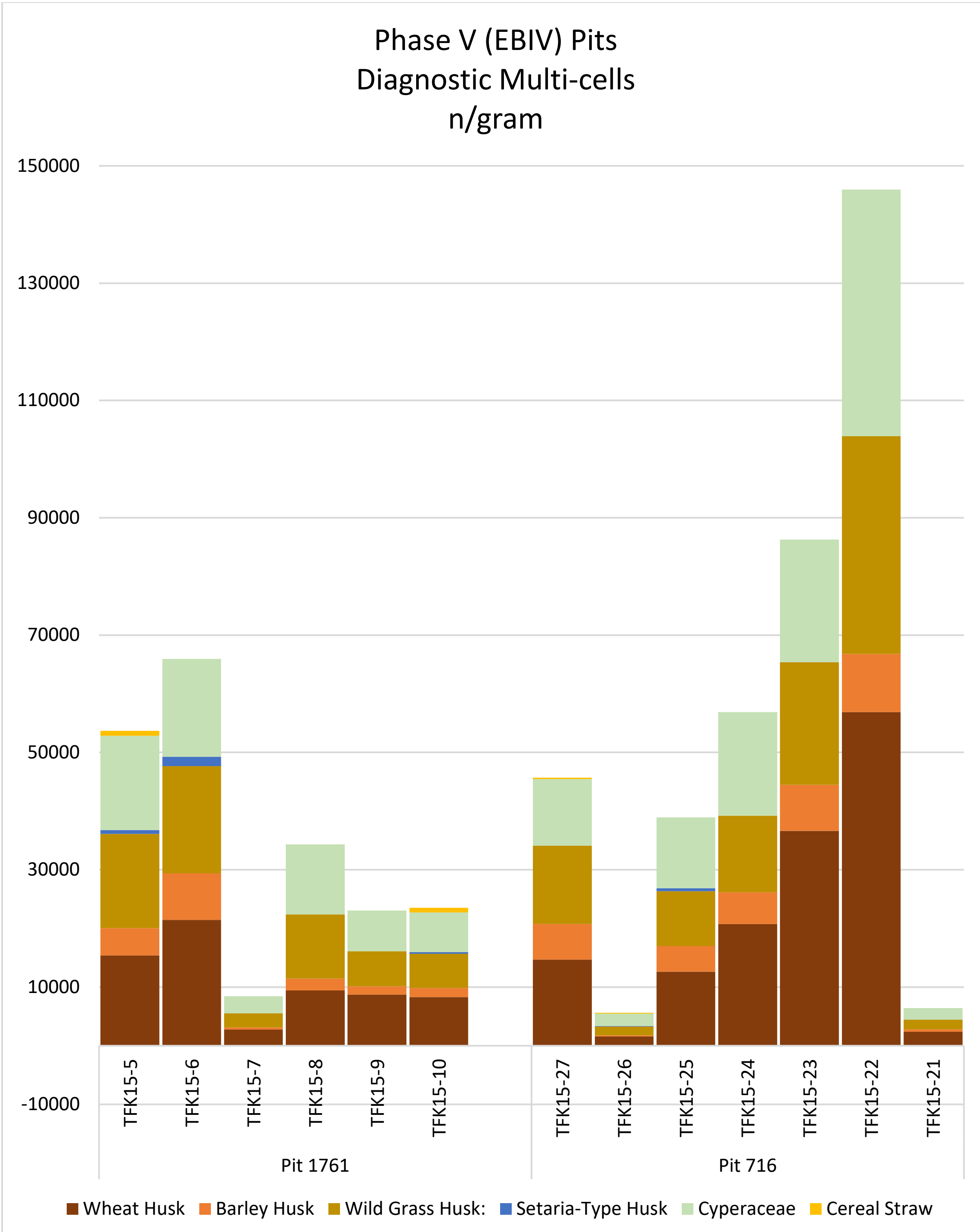
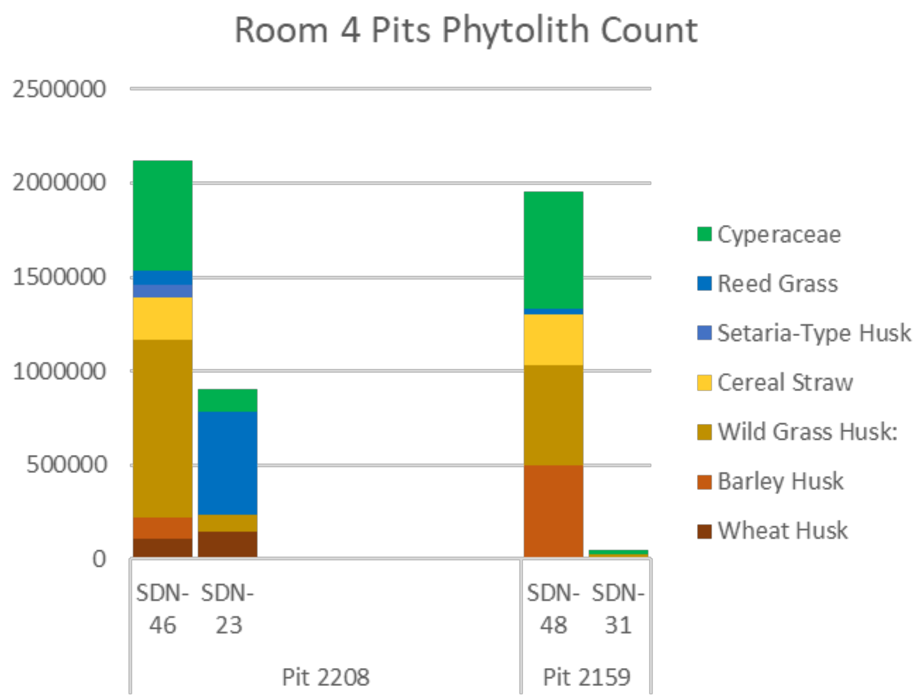


Figure 4.11: EBIV pit results, n/gram of all diagnostic multi-cell types. Each pit is represented from bottom (left) to top (right).

Figure 4.12: Sidon excavation (above) and the storage compartments from the EBA mud brick building (below), with arrow indicating where they are located within the College Site excavation.



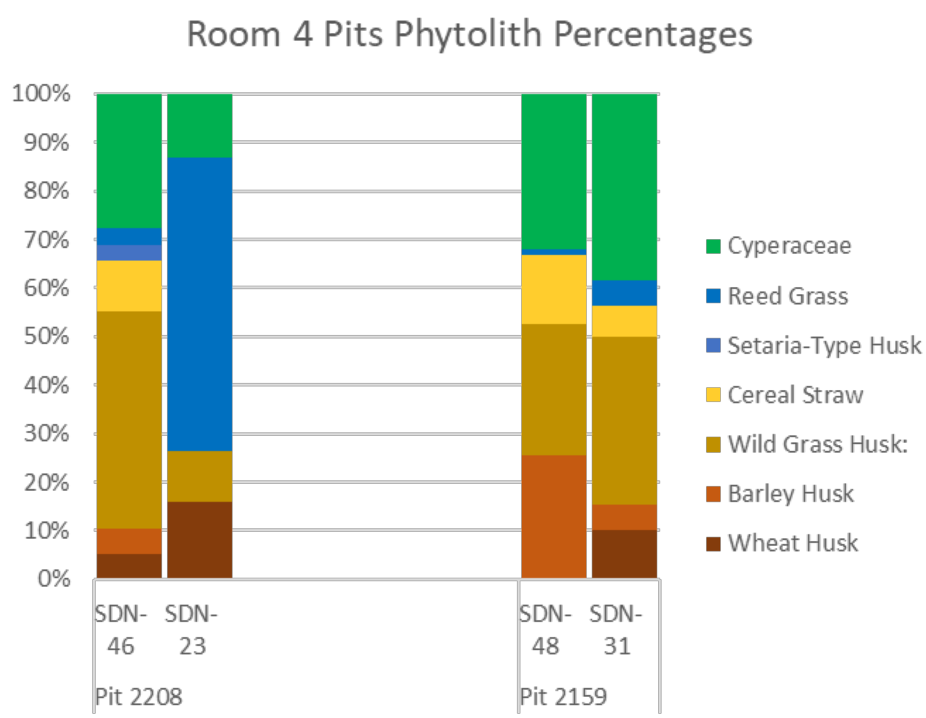


Figure 4.13: Room 4 from the Sidon EBA mud brick building, all diagnostic multi-cell phytolith types across two pits compartments. For each compartment, the lower sample is on the left and the upper sample is on the right. Presented in n/gram (above) and total sample percentage (below).

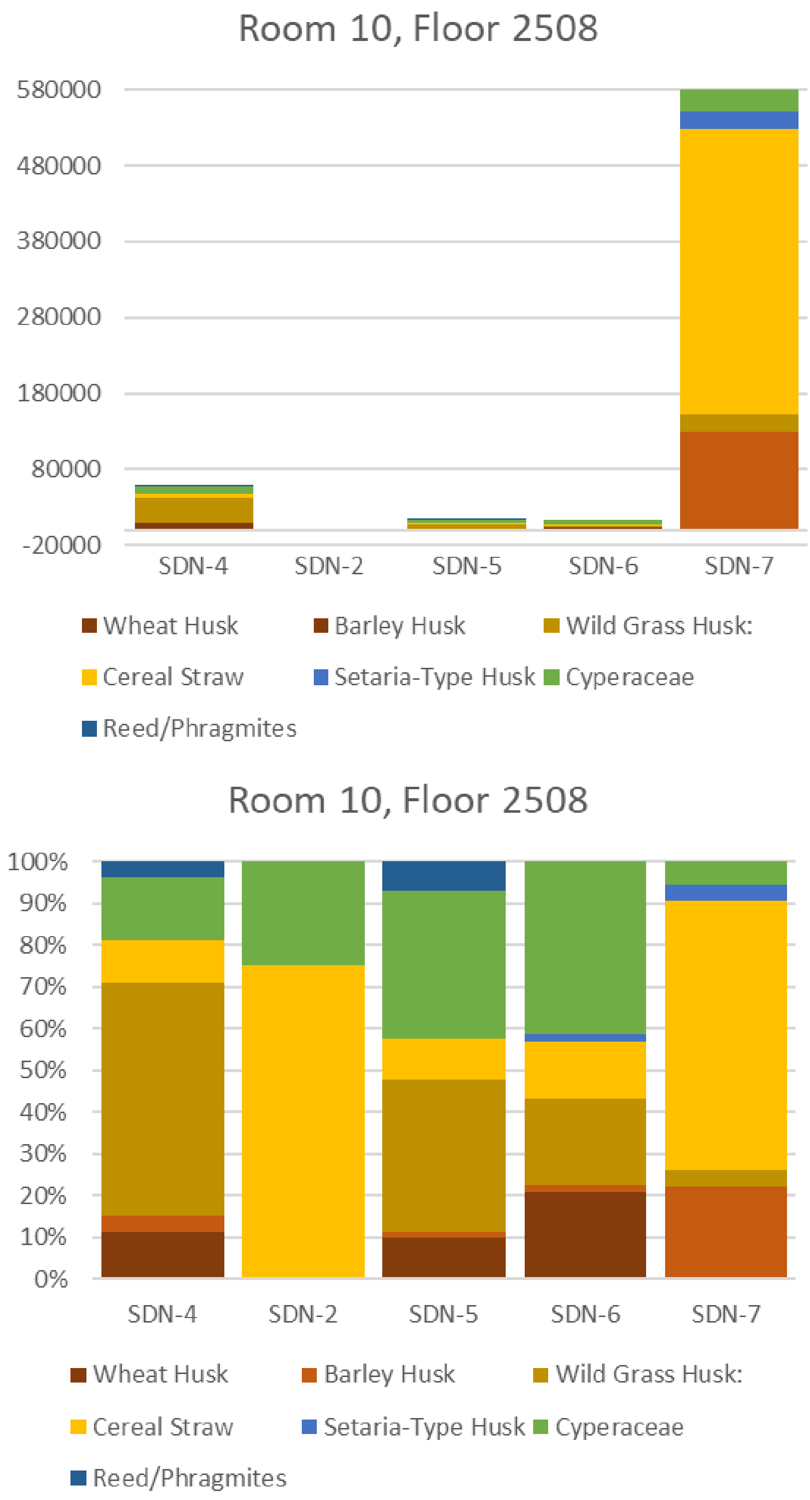
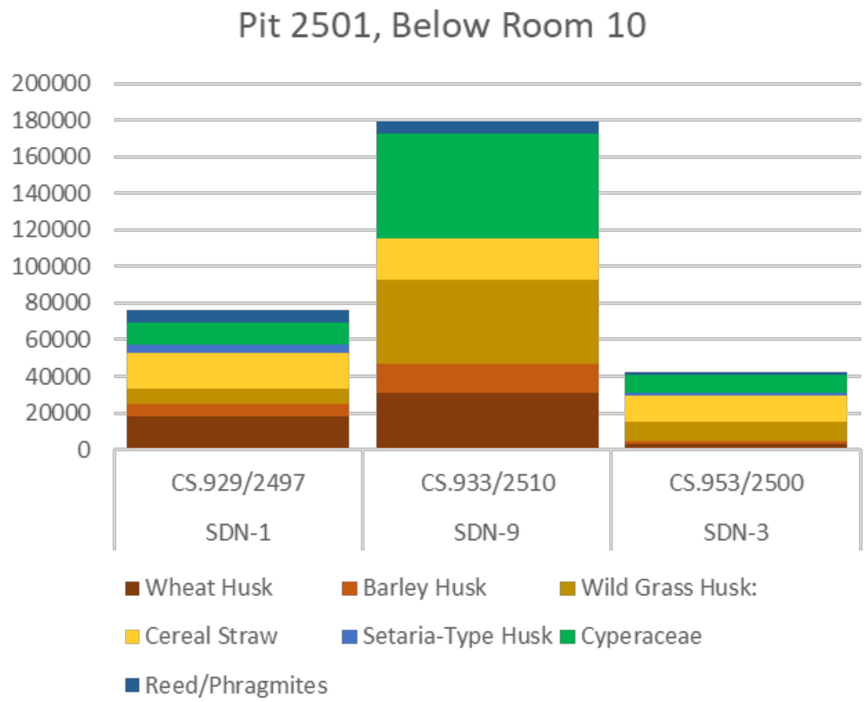


Figure 4.14: All diagnositc multi-cell phytolith types from floor 2508, in Room 10, Sidon EBA mud brick building. N/gram count (above) and sample percentage (below)



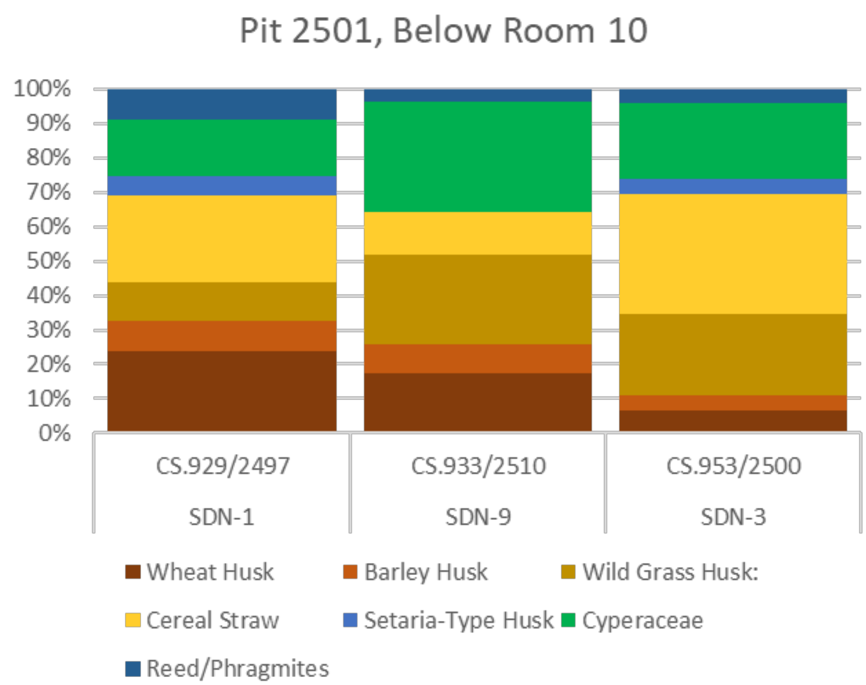
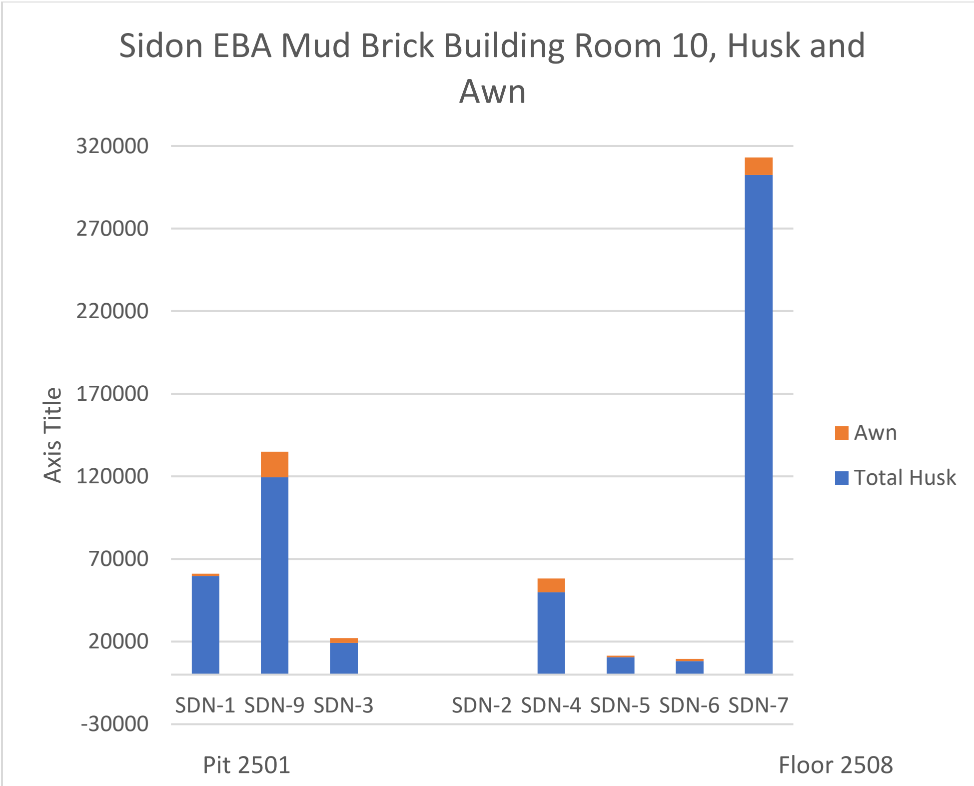


Figure 4.15: All diagnostic multi-cell phytolith types from compartment below Room 10 (adjacent to Floor 2508), Sidon EBA mud brick building. N/gram counts (above), total sample density (below).



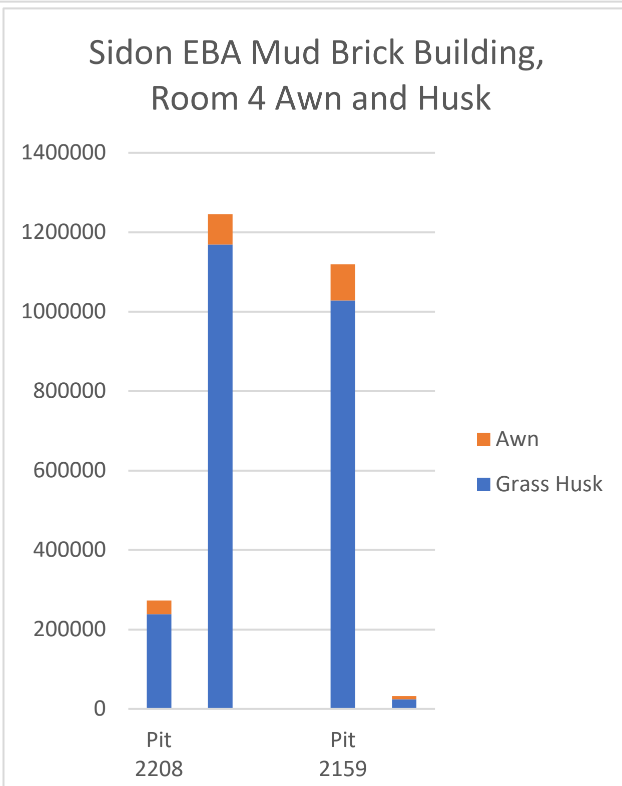


Figure 4.16: Husk and awn phytoliths from Room 10 samples (above) and Room 4 samples (below), Sidon EBA mud brick building.

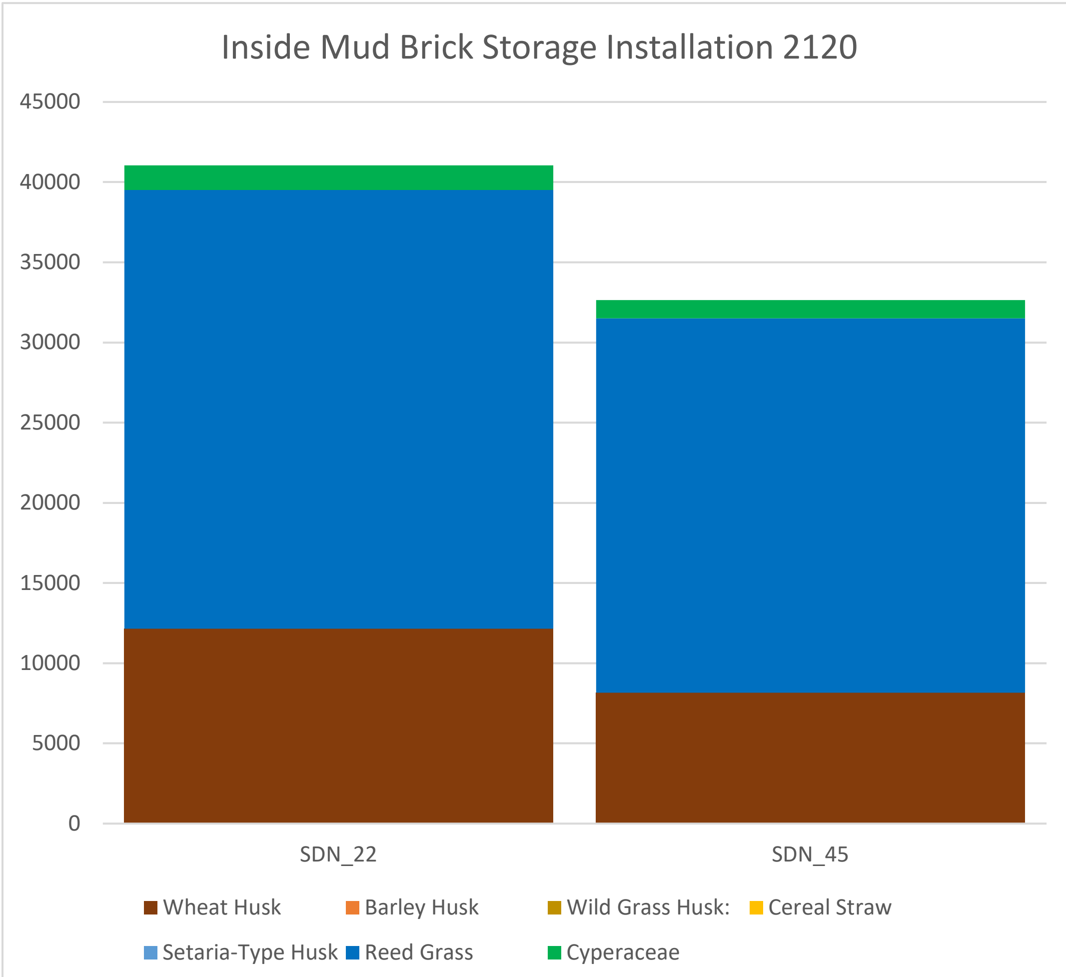


Figure 4.17: Diagnostic multi-cell phytoliths from samples taken within the mud brick "granary" installation 2120, just outside of the EBA mud brick building in the Sidon Museum Expansion excavations.

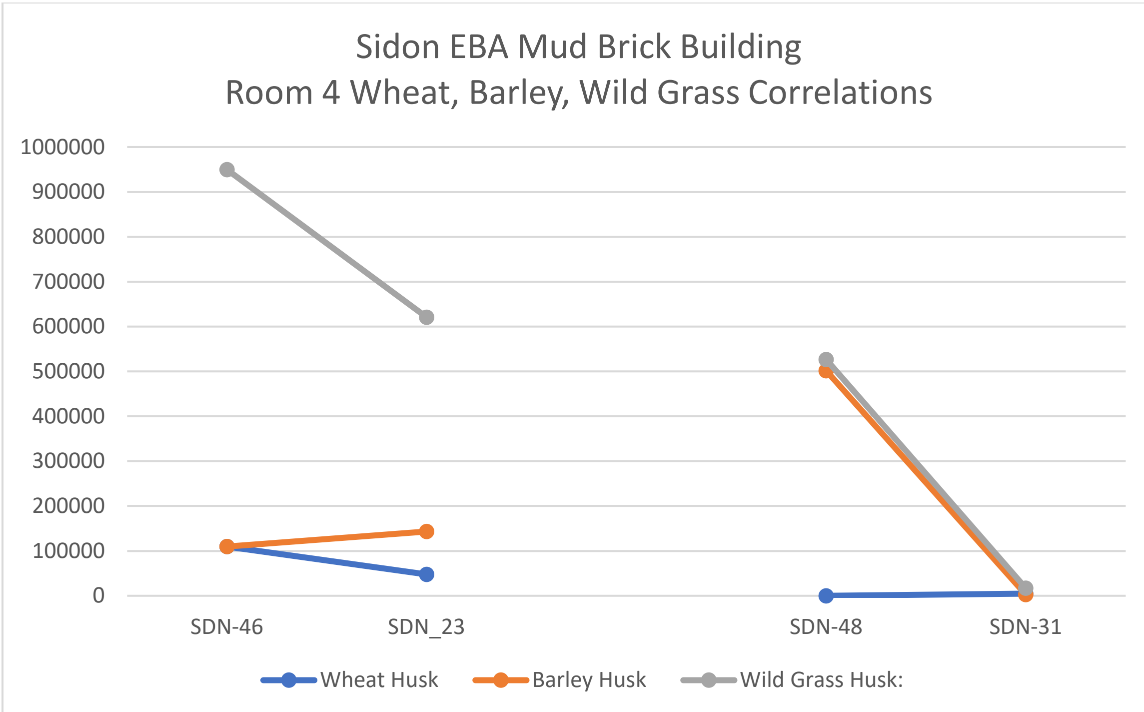


Figure 4.18: Correlations between multi-cell husk phytoliths for wheat, barley, and wild grasses in Room 4, EBA mud brick building at Sidon.

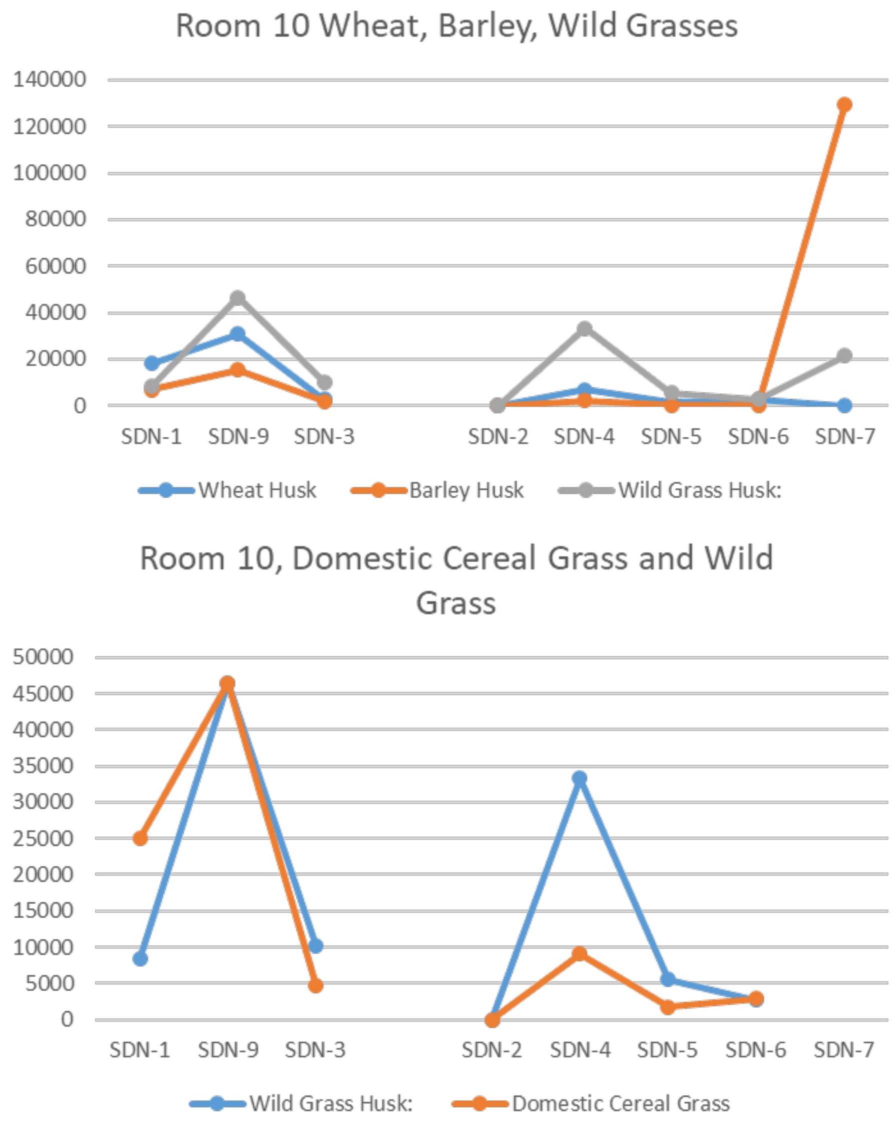


Figure 4.19: Correlations between wheat, barley and wild grass multi-cell husk phytoliths (above) and combined domestic cereal multi-cell husks and wild grass multi-cell husks (below), Room 10 in the EBA mud brick building, Sidon

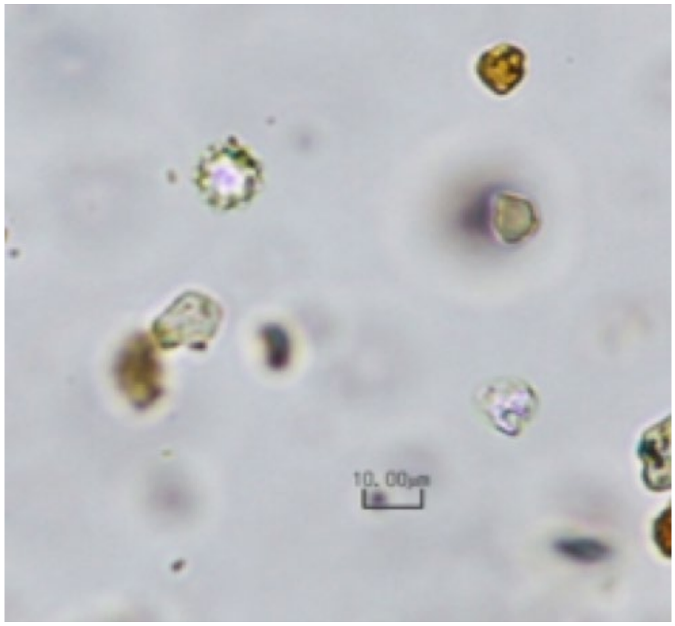


Figure 4.20: Echinate spheroid single cell phytolith from TFK

Figure 4.21: Neo-Assyrian "Sacred Tree" or "Tree of Life," with double King Ashurbanipal, from the Nimrud panels (first millennium BCE). Located at the British Museum, Photo Credit: British Museum
http://www.britishmuseum.org/collectionimages/AN00150/AN00150814_001

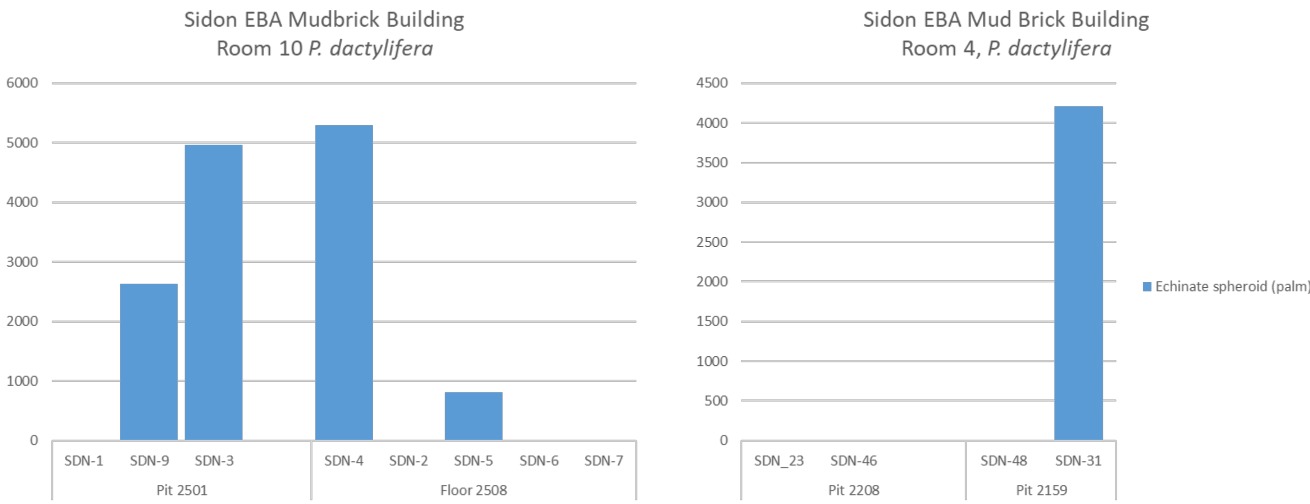


Figure 4.22: Echinate spheroid (palm, likely P. dactylifera) single cell phytoliths from Sidon EBA mud brick building rooms.

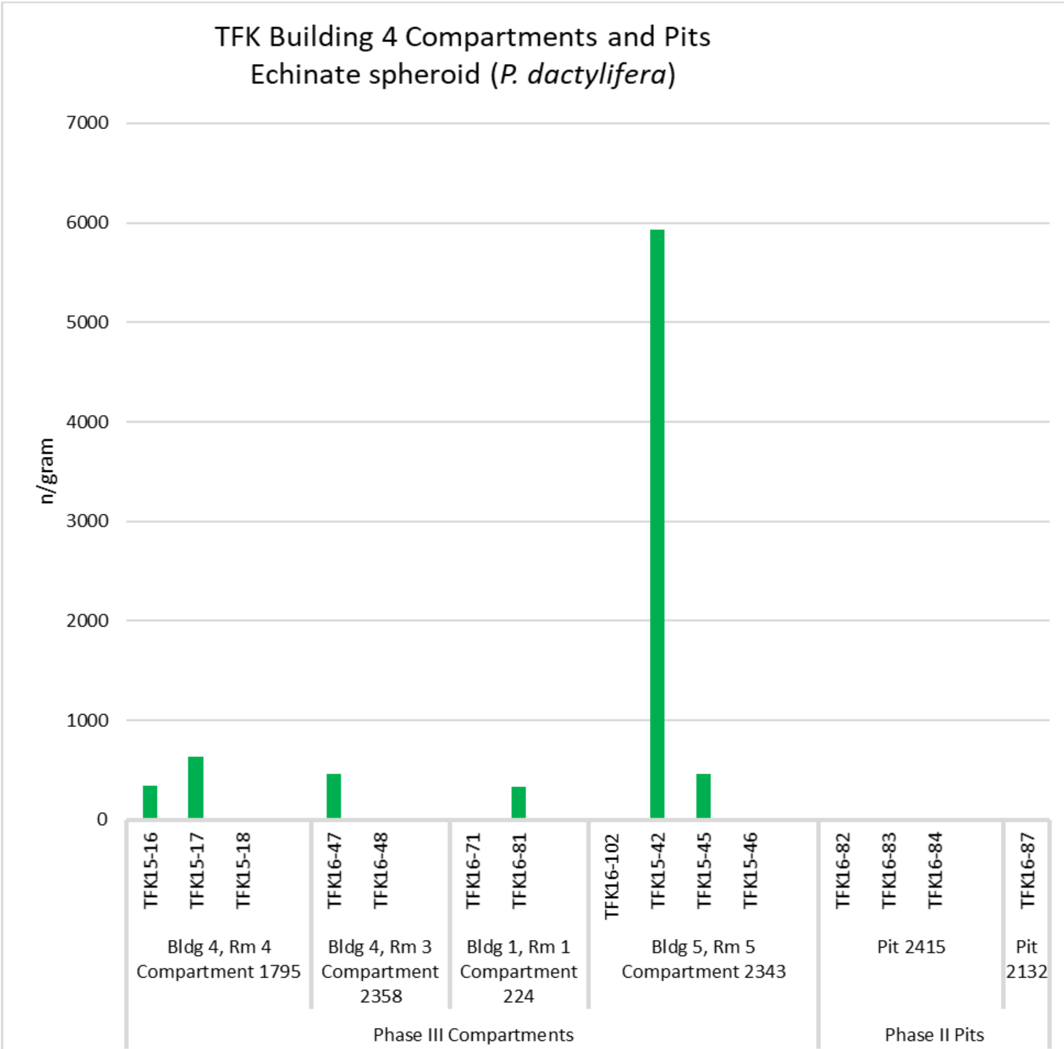


Figure 4.23: Echinate spheroid (palm, likely P. dactylifera) single cell phytoliths from TFK Phase II-III storage contexts

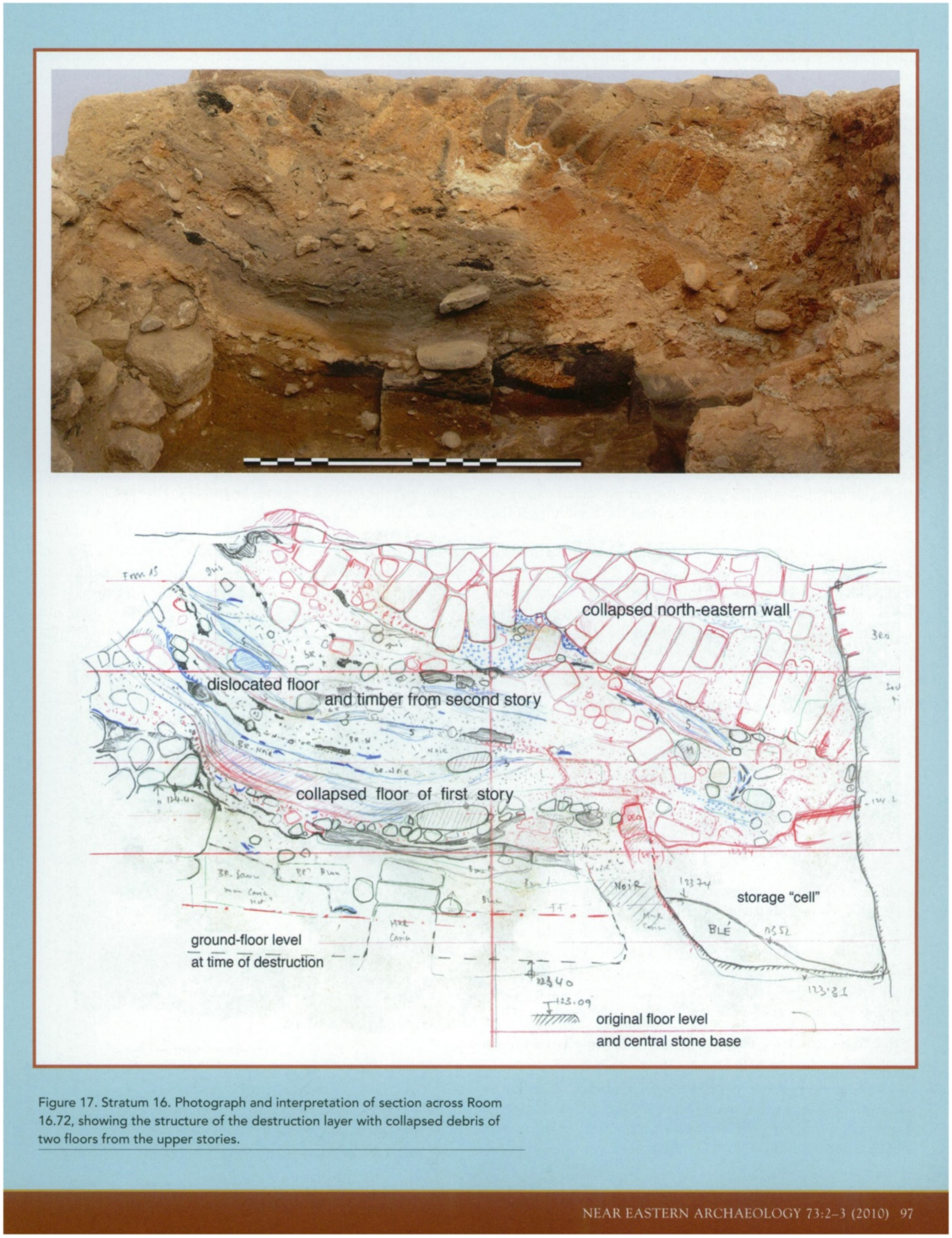


Figure 4.24: Photograph and drawing of burned and buried EBIII storage pit from Tell Arqa (Thalmann 2010: 97)

Figure 5.1: Specialized large-scale grinding room, including benches and discard installation, at Palace G, Ebla.

Figure 5.2: Example of a group of basalt fragments found together; note that the one on the right and the one at the top of the group have smoothed edges indicating reuse after breakage.

Figure 5.3: Examples of "miniature mortars" made from friable coastal sandstone, TFK.

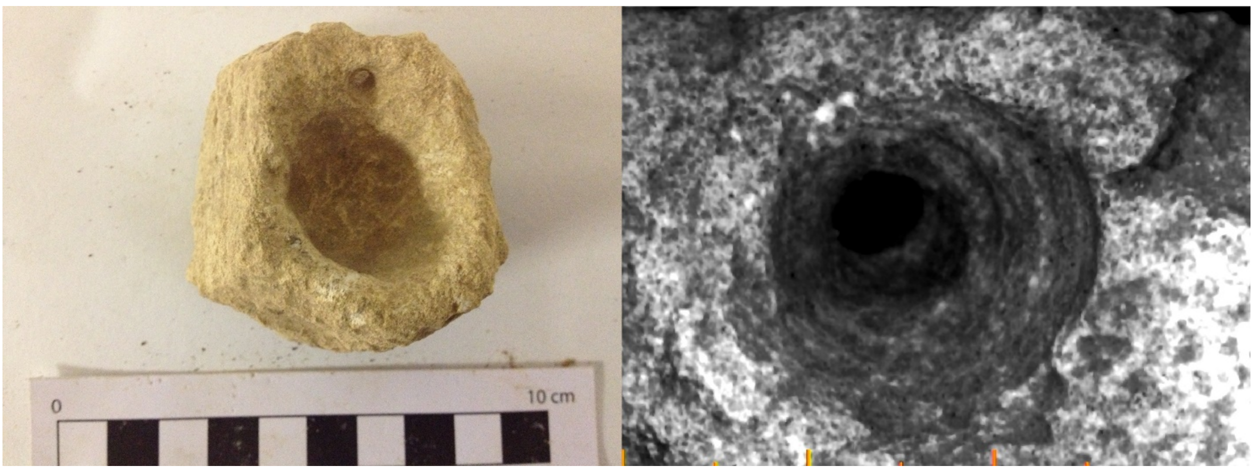


Figure 5.4: Miniature limestone mortar with drilled perforation, TFK.

Figure 5.5: Large stationary mortars in semi-public rooms, TFK: Building 4, Room 3 (left) is in the administrative complex; Building 1, Room 2 (right) is an EBII shared space, one of the few with street access.

Figure 5.6: Flat, ovate basalt slab from possible cooking context at Sidon

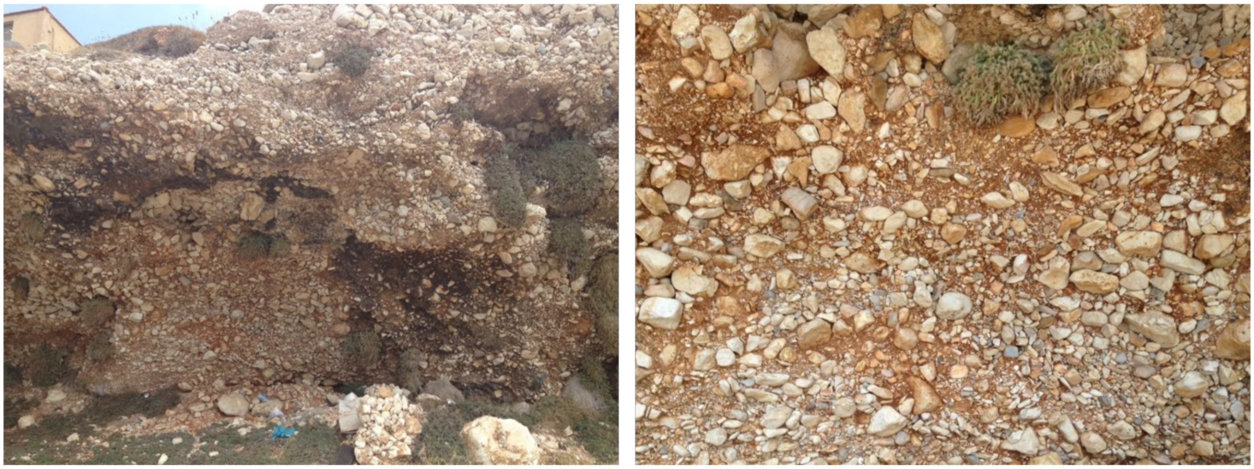


Figure 5.7: Erosional coastal section (left) and wadi section (right) near TFK from which raw material was gathered for experimental tool production.

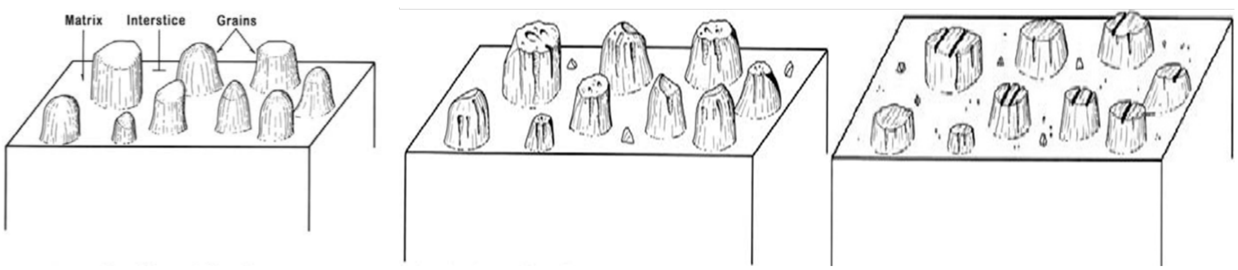


Figure 5.8: Adams' (2014) schematic drawings showing grain damage from different kinds of wear. From left to right: natural weathering, fatigue wear, and abrasive wear. Note that the grain wear affects not only the morphology of the grains, but the ways in which crushed parts of the grains fill the interstices. Credit: Adams 2014.

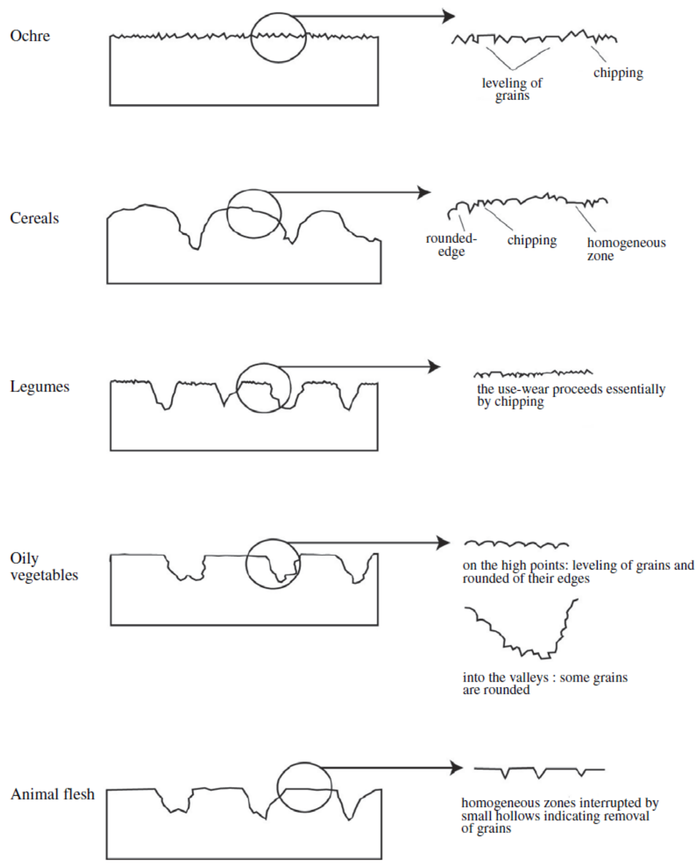


Fig. 2. Use-wear characteristics for each category of processed material distinguished in this study, with special focus on microrelief and grain surface modification.

Figure 5.9: Dubreuil's 2004 schematic drawing of the effect of different texture processing on stone micro-topographies. Credit: Dubreuil 2014.

Figure 5.10: Adams' (2014) schmatic rendering of tribochemical reaction and build-up to form micropolish.

Figure 5.11: Manufacturing and processing with experimental tools at Trent University, 2013

Figure 5.12: Manufacturing and processing experimental material and tools at AUB, Beirut, Lebanon 2016

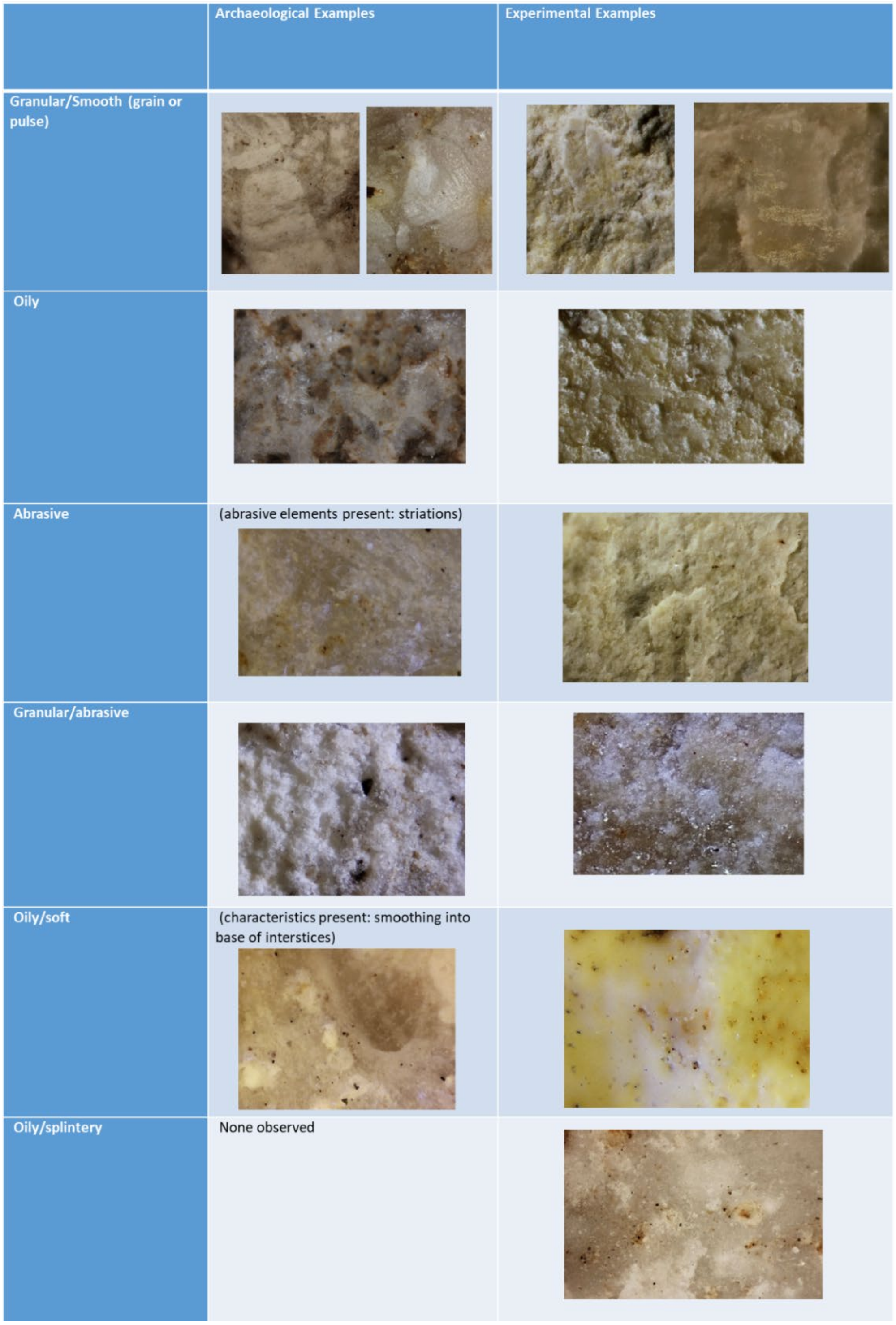


Figure 5.13: Simplified chart comparing observed characteristics for each texture type on archaeological stones compared to experimental stones. Specific criteria are described in detail with associated photos in the charts per material type in Appendix Three. Important characteristics for comparison archaeologically are described in the text of Chapter Five. Comparisons are not meant to be seen as exact, but rather show some of the comparable characteristics of wear patterns associated with each texture type.

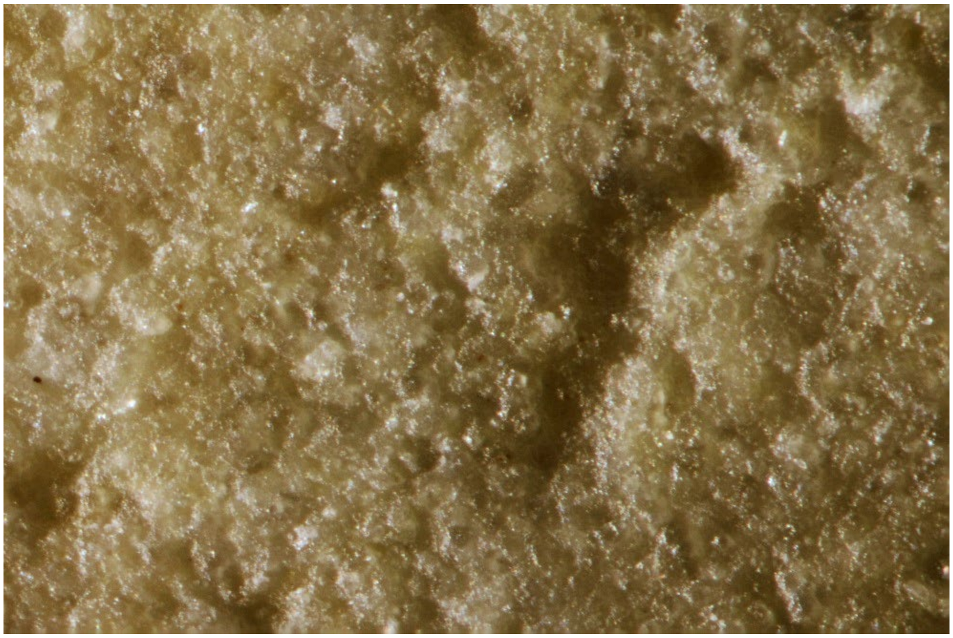


Figure 5.14: Experimental flax grinding tool under DIC lighting showing the "double relief" of generalized shine that appears to hover above the underlying sinuous micro-topography (x50 magnification).

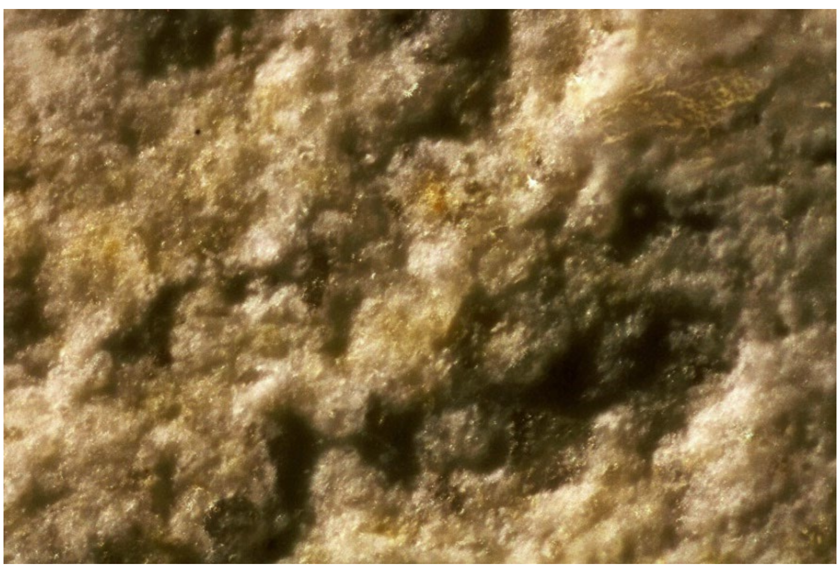


Figure 5.15: Experimental barley grinding tool showing generalized shine under regular cross-polarized light. This gives off a strong reflective shine and can obscure underlying topography. X100 magnification

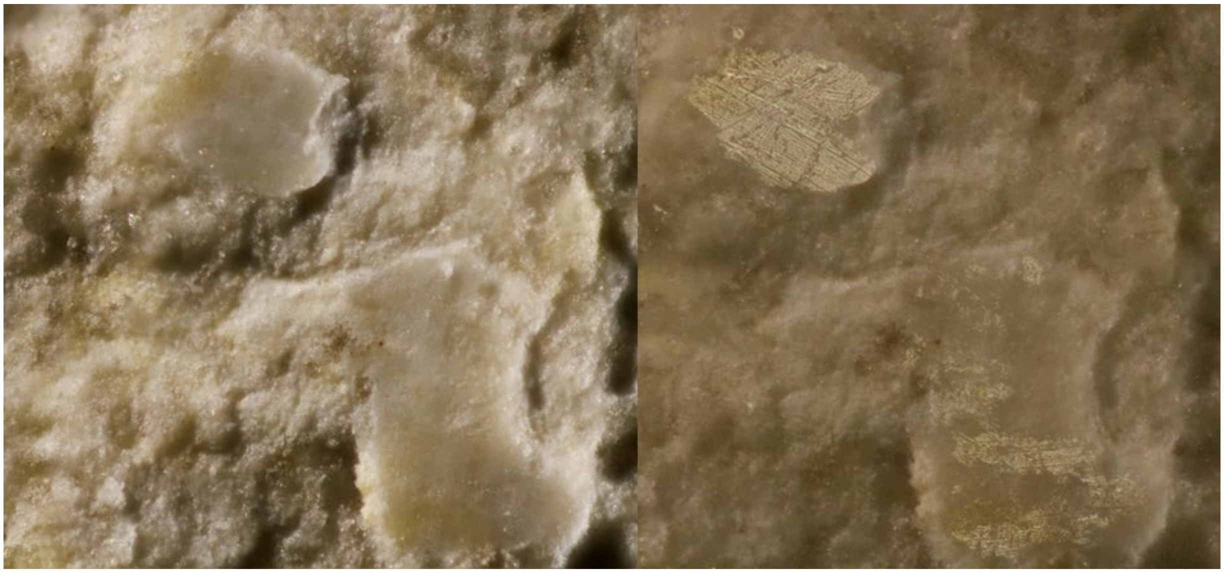


Figure 5.16: Experimental barley grinding tool, without DIC (left) and with DIC (right) showing development of micropolish on compressed powder plateau surfaces. x200 magnification.

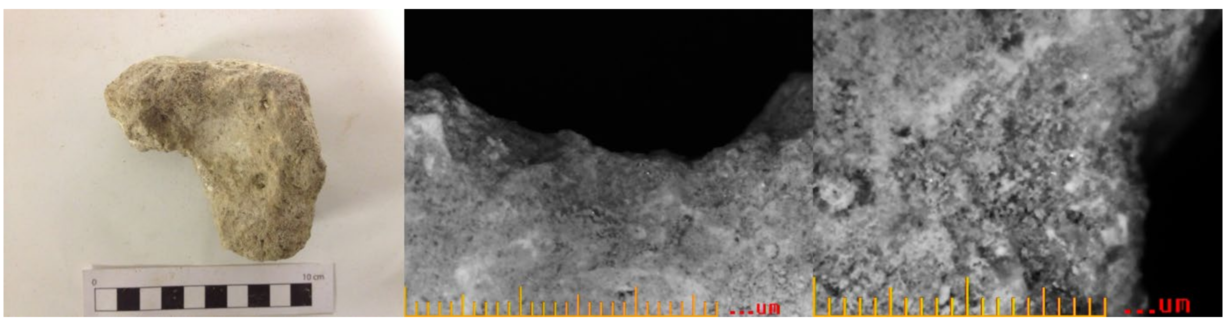


Figure 5.17: Limestone grinding slab 290.300.285 from TFK, broken before point of exhaustion and x100 magnification images of flaking/chiseling scars along the fracture point, indicating intentional breakage.

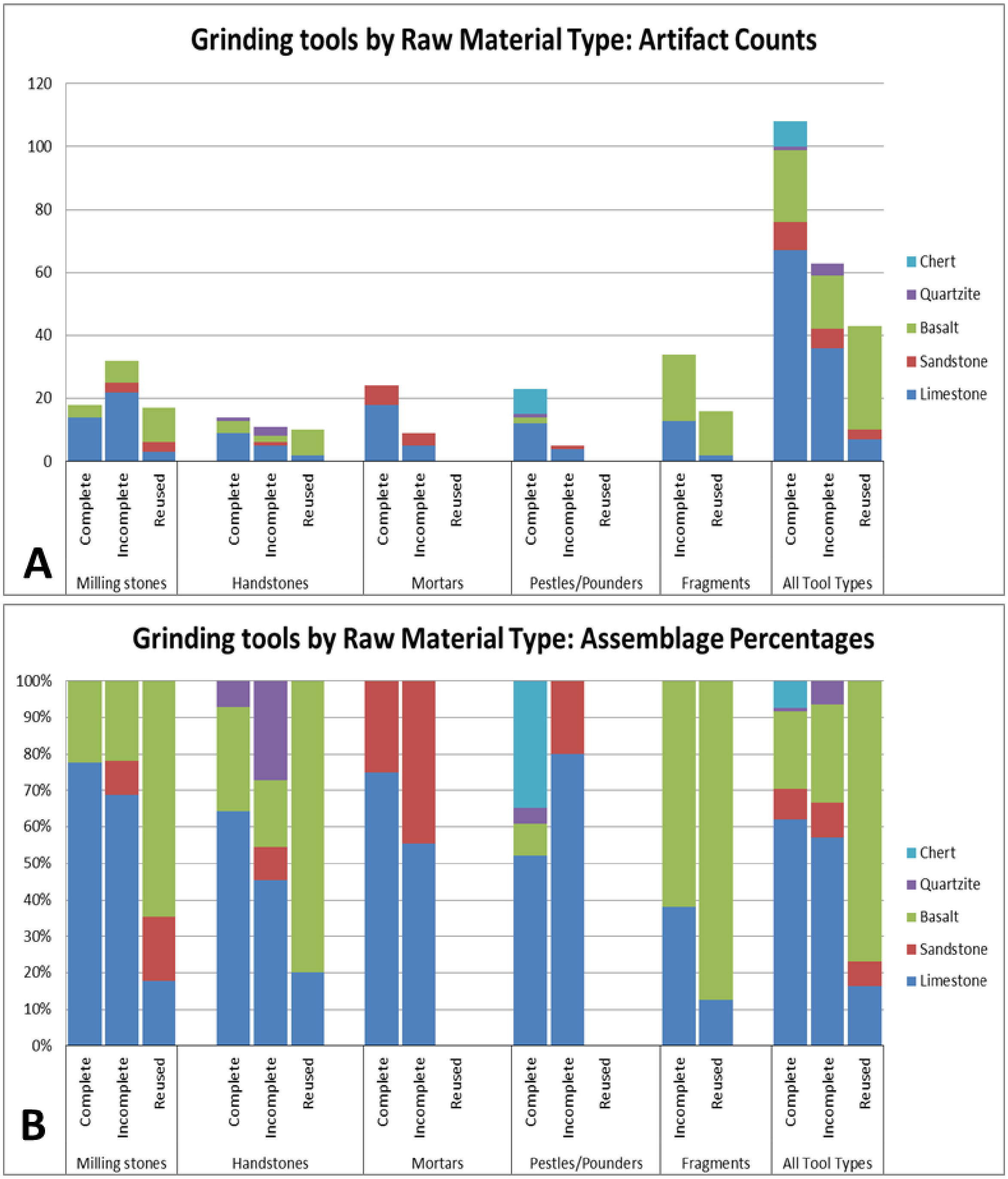


Figure 5.18: TFK ground stone tools by raw material type; presented by actual count (A) and by percentage of each type (B).

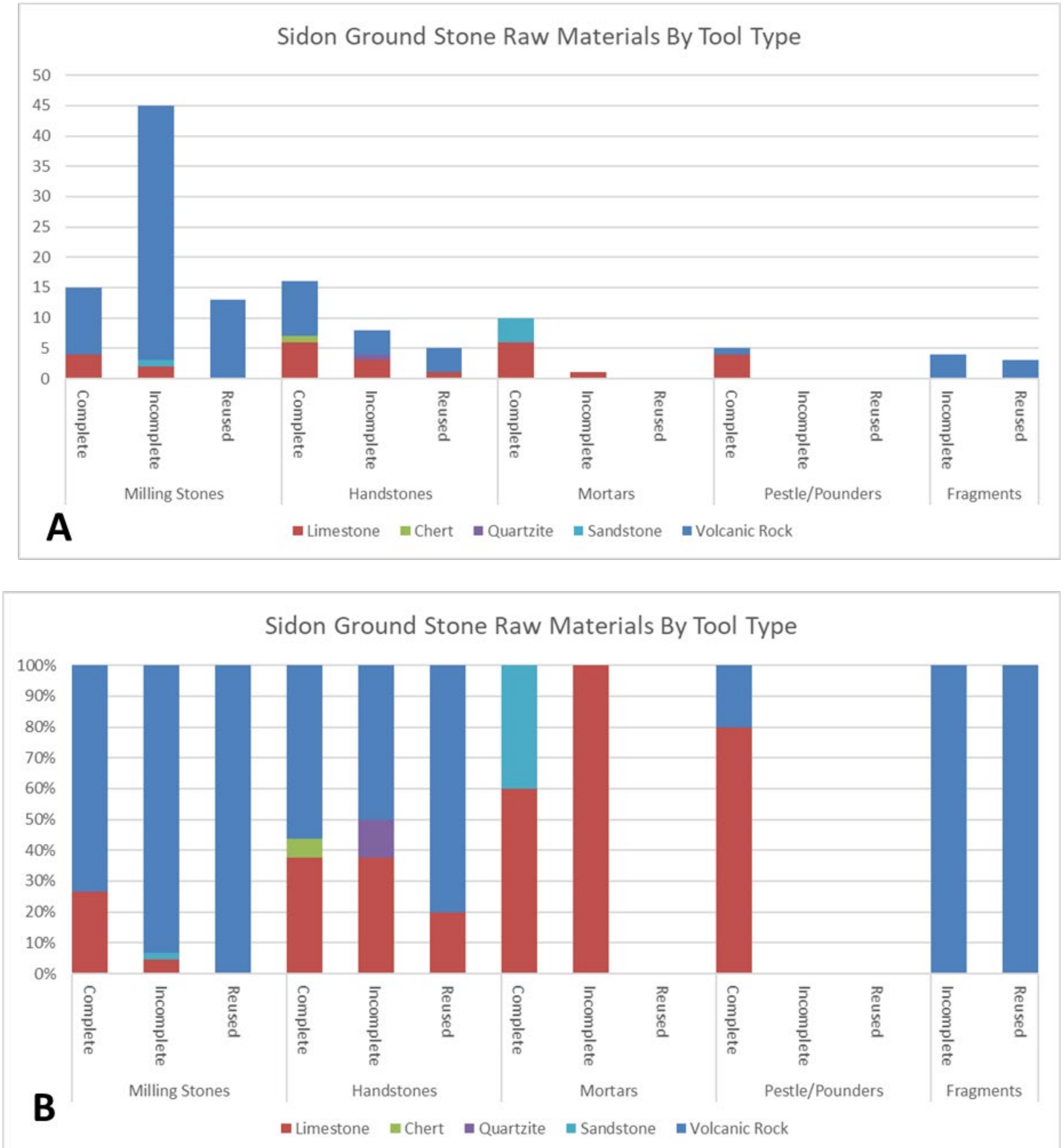


Figure 5.19: Sidon EBA ground stone tools types by raw material type. Presented in absolute counts (A) and percentage of type (B).

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Appendix One

Phytolith Processing Protocol and Counting Sheets

PHYTOLITH PROTOCOL (adapted from A. Miller Rosen, 1999)

1. Take 0.8g of sediment from sites where a high density is expected. If you expect the density to be low you can use up to 5g. Sift sample through a 0.5 for large skeletons/ 0.25 mm sieve. Record weight.

CARBONATE REMOVAL

2. Use 15ml of 10% HCL to remove the pedogenic carbonates (from 0.8g sediment). When the fizzing stops, wash in distilled water then centrifuge at 2000 rpm for 5minutes. Pour off the suspense. Repeat twice more. If you don't have a centrifuge you can let the liquid sit until the suspense is clear and pour or pipette off.

CLAY REMOVAL

3. Let the samples sit overnight in a little distilled water to help disperse the clays. The next day pipette off the excess water and add a dispersant such as Sodium hexametaphosphate (Calgon) or Sodium pyrophosphate (You can make up a stock solution by adding 50gm powder to 1 litre distilled water). Add about 15 – 20 ml of this solution to each sample and stir/shake vigorously. Pour the sample into a tall beaker washing out all the sediment and add distilled water up to a height of 8cm (the height is important for settling out the sand and silt sized particles). Stir well (washing stirrer into the beaker) and let the samples sit for exactly 1 hour and 10 minutes. Pour off the suspense with the clays. Refill jars to exactly 8cm again, stir and this time let it sit for exactly 1 hour before pouring off the suspense. Repeat this step until the suspense is clear. Then pipette into a ceramic crucible and leave in a drying oven at less than 50ºC. If higher it will bind clays. Leave overnight to dry.

ORGANIC MATTER REMOVAL

4. Take the sample (which should now consist of sand and silt sized particles. Break up any lumps. Put in a muffle furnace for 2 hours at 500ºC (2 ½ if putting them into a cold furnace).

PHYTOLITH SEPARATION

5. Use a 15ml polypropylene centrifuge tube for this stage. Fill each tube with 3ml Sodium polytungstate solution, which has been calibrated at 2.3 sp gravity. Then add the sample by scraping it onto folded shiny paper and pouring into the tube. Close cap on tube and shake well. Put in centrifuge (make sure the weights of tubes in opposite positions are exactly matched). Run the centrifuge at 800rpm for 10 mins.

6. Remove tubes and pour suspense (which has the phytoliths) into clean 15 ml tubes. Add distilled water to the tubes with the phytoliths and centrifuge at 2000 rpm for 5 mins. Now the phytoliths are at the bottom of the tube. You can pour off the suspense through a filter into a wash container for later recovery and recalibration. Add water and wash 2 more times.

7 Remove the clean phytoliths by pipetting them into a small container (like a 5 or 10 ml beaker) and dry.

MOUNTING

8. After they are dry weigh the phytoliths. Then mount 2- 3mg (record weight mounted). Using fume cupboard pour a few drops of Entellen (the same size as the cover slip) onto the clean slide. Add the phytoliths and stir with toothpick to get even distribution. Place cover slip over Entellen avoiding bubbles – don't press down!

Phytolith Counting Template

SITE:	
Sample:	
Context	
SINGLE-CELL	Count
Long (Smooth):	
Long (Sinuate)	
Long (Rods)	
Long (Dendritic):	
Papillae:	
Hairs:	
Trichomes:	
Bulliform:	
Ovals	
Keystone	
Crenates:	
Bilobes:	
Rondels:	
Saddles:	
Cones:	
Flat Tower:	
Horned Tower:	
Rugulose Spheroid	
Smooth Spheroid	
Bottle-Shape	
Stipa-Type Rondel	
Elongate	
Tracheids	
Two-Tiered	
Blocks	
Platey	
Sheet	
Single Polyhedron	
Scalloped	
Single Jigsaw puzzle	
MULTI-CELL	Count
Leaf/Stem:	
Unident Husk:	

Wheat Husk	
Barley Husk	
Aegilops	
Wild Grass Husk:	
Cyperus	
Phragmites Stem	
Awn	
Panicoid	
Bromus-type Stem	
Avena	
Setaria-Type Husk	
Phragmites Leaf	
Cyperaceae	
Cereal Straw	
Scirpus-type	
Square-cell leaf/stem	
Polyhedron	
Polyhedral hair base	
Multi-Tiered forms	
Verrucate	
Coarse Verrucate	
Round Diatoms	
Wt. % Phytoliths	
Ratio M-C/S-C	
Ratio Floral/Stem	
Sample:	

Phytolith Morphotype Descriptions from Ramsey Niccolaides 2015 (Table 4.1, p 123)

Phytolith Morphologies	ICPN alternative	Ecozone-type	References to identification criteria/comments
Single cell forms			
Psilate long cell[G~]	Elongate psilate margin		Most frequently found in grass stems (Metcalf 1960; Twiss 1992).
Sinuate long cell[G~]	Elongate sinuate margin		
Echinate long cell[M]	Elongate echinate		
Dendritic long cell[G]	Elongate dendritic	Steppe/Parkland Grasses	Found in grass husks (Novello and Barboni 2015; Rosen 1992).
Rod smooth long cell[M]	Elongate psilate tenuous		
Psilate echinate asymmetrical long cell[M]	Elongate echinate assymetrical		Mostly found in the leaves rather than stems of grasses and sedges (Ryan 2009).
Hairs[MD]			Mainly found in grass epidermis (Metcalf 1960).
Trichomes[M]			Mainly found in grass epidermis (Metcalf 1960).
Papillae[G]		Steppe/Parkland Grasses	Found in grass husks.
Stomata[MD]			
Bulliform[G]			Found in the leaves of grasses, also known as motor-cells (Metcalf 1960).
Keystone Bulliform ('Fan-shaped') (cf. reeds)[G]	Cuneiform bulliform cell	Wetland	Commonly occur in grass species that favor watery habitats (Sangster and Parry 1969). Cf. to Lu, et al. (2006) fan-shaped reed.
Crenates[G]			
Bilobe short cell[G]			Generally panicoid grasses, see Twiss, et al. (1969).
Polylobate short cell[G]			Generally panicoid grasses, see Twiss, et al. (1969).
Cross short cell[G]			Generally panicoid grasses, see Twiss, et al. (1969).
Saddle short cell[G]			Generally chloridoid grasses, see Twiss, et al. (1969).
Rondel short cell[G]			Generally pooid grasses, see Twiss, et al. (1969).
Sedge cones[M]		Wetland	See Ollendorf (1992), Ollendorf, et al. (1987), Metcalf (1971), and Le Cohu (1973).
Globular echinate (spheroid) (cf. palms)[M]			Found in palms (Rosen 1992).
Globular granulate (spheroid)[MD]			
Globular psilate (spheroid)[D]		Woodland	Found mainly in dicot wood, cf. to Albert, et al. (2003) spheroid psilate.
Blocks[DM]		Woodland	Found mainly in dicot wood, cf. to Albert, et al. (2003) parallelepiped block forms.
Platey (sheet)[DM]		Woodland	See Bozarth (1993). Found mainly in dicot leaves, cf. to Albert, et al. (2003) platelet.
Single polyhedron[D]		Woodland	Found mainly in dicot leaves (Albert, et al. 2003; Bozarth 1992)
Scalloped (after Bozarth)[D]		Woodland	See Bozarth (1992).
Single jigsaw puzzle[D]		Woodland	See Bozarth (1992), Tsartsidou, et al. (2007). Found mainly in dicot leaves (Albert, et al. 2003; Bozarth 1992).
Verrucate[DM]		Woodland	See Bozarth (1992).

Coarse Verrucate^{DM}		Woodland	Found mainly in dicot leaves (Bozarth 1992).
Irregular scrobiculate^{DM}		Woodland	
Honeycomb^{DM}	Favose	Woodland	See Bozarth (1992). Found mainly in dicot leaves (Albert, et al. 2003)
Tracheids^{DM}		Woodland	Found mainly in dicot leaves, cf. to Albert, et al. (2003) tracheary.
Indet dicot		Woodland	
		Multi cell forms	
Unident monocot leaf/stem^{M}			
Leaf/stem psilate long cell$^{G\sim}$			See single cell description.
Leaf/stem sinuate long cell$^{G\sim}$			
Leaf/stem echinate long cell^{M}			
Leaf/stem stomata^{M}			
Leaf/stem bilobe^{G}			See single cell description.
Leaf/stem polylobate^{G}			See single cell description.
Leaf/stem cross^{G}			See single cell description.
Leaf/stem saddle^{G}			See single cell description.
Leaf/stem rondel^{G}			See single cell description.
Stacked Bulliforms^{G}		Wetland	Found in the leaves of grasses. Higher silicification may indicate a wet or submerged growing environment (Andrejko and Cohen 1984; Bremond, et al. 2005; Sangster and Parry 1969).
Square cell leaf/stem^{MD}			
Cyperaceae – rods + long cells^{M}		Wetland	Rods and long cells overlapping – possible to see under different foci under magnification.
Cyperaceae – sedge cones^{M}		Wetland	See Ollendorf (1992), Ollendorf, et al. (1987), Metcalf (1971), and Le Cohu (1973).
Phragmites (reed) culm^{G}		Wetland	See Ryan (2009).
Phragmites (reed) leaf^{G}		Wetland	See Ryan (2009).
Grass Husk^{G}		Steppe/Parkland Grasses	
cf. Wheat Husk^{G}		Steppe/Parkland Grasses	See Rosen (1992).
cf. Barley Husk^{G}		Steppe/Parkland Grasses	See Rosen (1992).
Cereal straw^{G}		Steppe/Parkland Grasses	See Rosen (1992, 1993).
Awn^{G}		Steppe/Parkland Grasses	See Rosen (1992).
Polyhedron^{D}		Woodland	Found mainly in dicot leaves (Albert, et al. 2003; Bozarth 1992).
Polyhedral hair base^{D}		Woodland	Found mainly in dicot leaves (Albert, et al. 2003; Bozarth 1992).
Silica aggregate^{D}			
Indet multi cell			

Key: ^{G} grasses, $^{G\sim}$ mainly grasses, ^{M} monocot, ^{D} dicot.

Appendix Two

Use Wear Pilot Study Protocol and Observations Sheets

Alison Damick

Use Wear Experimental Protocol

11 October 2013

Background questions: What is the nature of change in the archaeological record, what material is foregrounded to identify it, backgrounded materials are actually more fully part of social and political collectives (acting back on bodies, affording new relationships), ground stone in the midst of food production is a window into this kind of intimate space – what does telling the story of this 'pivotal' moment at TFK through GS food production tools look like?

Multi-method approach: morphologies, raw materials, use wear, residue analyses, contextual/spatial analyses (life histories).

Use Wear Hypothesis: There will be identifiable patterns of processing techniques and materials associated with unique tool materials and types.

Protocol:

1. **Purpose**:
    a. For the project overall: To identify the types of materials being processed by the ground stone tools associated with food production and consumption spaces over the course of settlement history at TFK. If possible, to also identify variations in processing techniques on tool types as visible on the surfaces of the stones (ie, pressure from above, rotary vs lateral, thrusting percussion vs pounding/crushing).
    b. For this exercise: To identify the types of use that result on the surfaces of raw materials from around TFK when processing different materials and with different motions.
2. **Materials**:
    a. microscope – stereoscopic, confocal, but also other? Will SEM be useful?
    b. Raw stone materials: three kinds of limestone, one kind of basalt
    c. Processing materials: by texture, hard/granular: salt; hard, grainy: barley or lentil; soft, fibrous: emmer wheat; soft, oily: flax; maybe an animal protein too (ie, like kibbe)?
3. **Methods**:

a. Clean all stone samples and describe them macroscopically and under OM before any use.
b. Break apart to six stones per material type (do I have enough for this?)
c. Use one side of each stone for lateral grinding, the other side for rotary grinding, and perhaps the poles for pounding/crushing?
d. Process, with each stone/material/motion combination, at least four hours.
e. Examine under OM at different stages throughout (maybe every 30 minutes?)
f. PROBLEM: that's a lot of hours. Can I parse this down for now, find a place to start, and then extend the experiment later in the field?

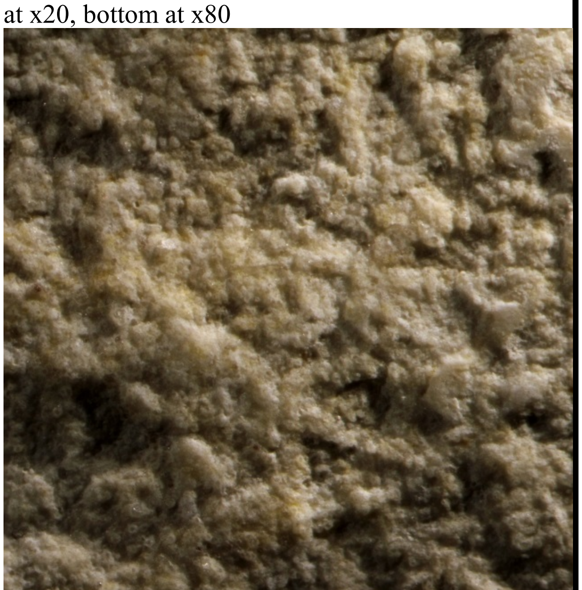
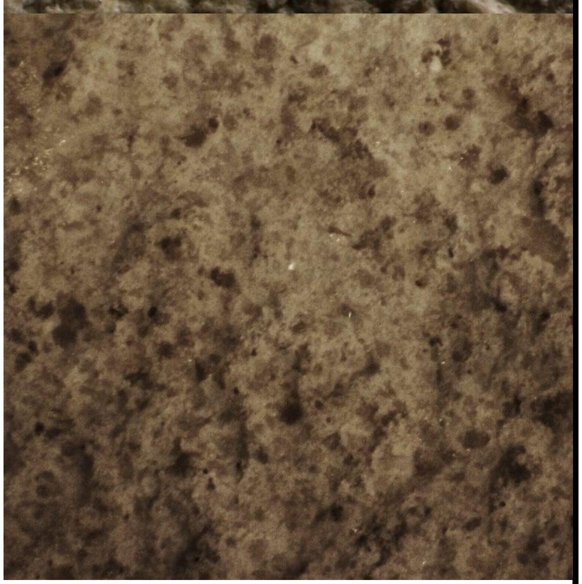
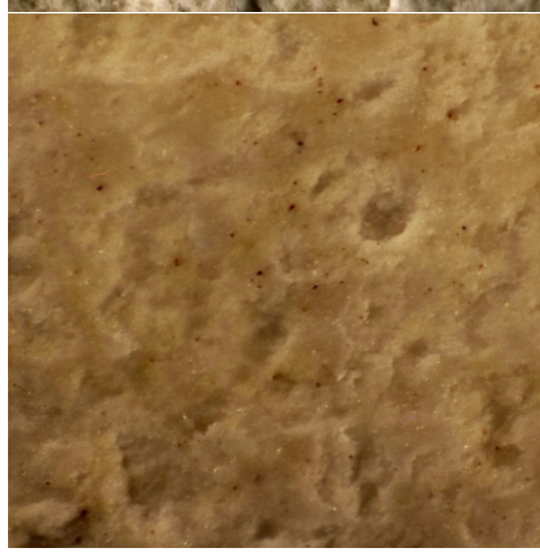
4. **Controls**:
   a. Base material: should be limestone? As that's most common on site? Or should I control by keeping like to like?
   b. Grinding motion per experiment, also grinding time (all will be ground with same motion for same amount of time)
   c. Test variable: Variable 1 is the material being processed. Variable 2 is the motion of processing.
5. **Data Interpretation**:
   a. Microscopic images will be produced from different areas on the surface of the used stones and compared – to some extent, this will be qualitative analysis. At this point the only interpretation offered will be detailed descriptions of use type and variation over time: ie, surface topography, individual grain wear, linear traces and reflectivity. These will compile an initial reference database to be compared against archaeological samples from TFK.

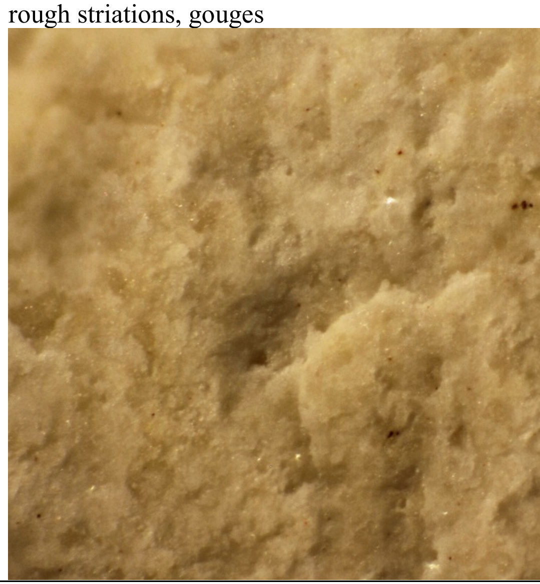
Trent University, Fall 2013
Description of Preliminary Experiments

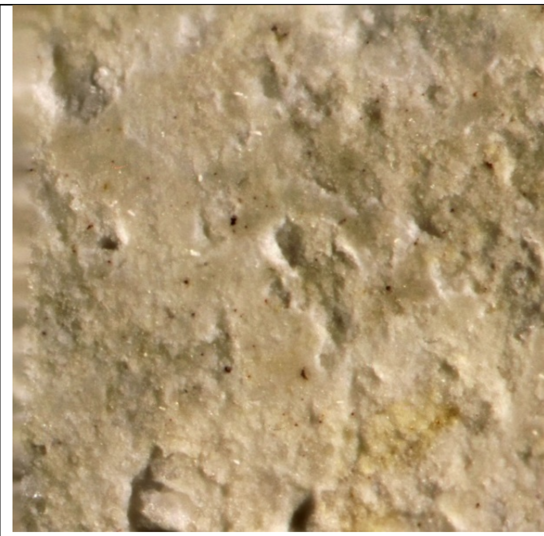
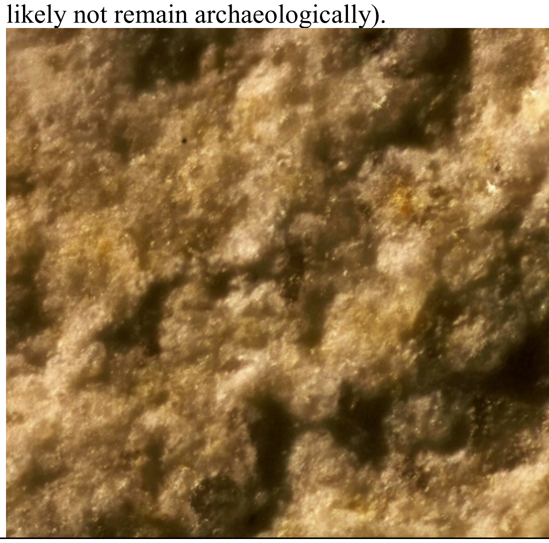
RAW MATERIAL DESCRIPTION: **Geological classification**: limestone (Sannine formation, probably upper levels; generally non-fossiliferous) **Texture** (beneath the cortex): Clastic, well-sorted, fine-grained, isotropic, non-porous **Mineral constituents**: fairly pure calcium carbonate with frequent quartz crystals.			
Low Magnification			
Establish multiple possibilities/ranges for each characteristic observed, so that you can describe multiple possibilities and combinations.	**Barley**	**Salt**	**Flax**
ASPECT **Focus on plateaus for roughness (topo is amount of plateau vs pecked surface, roughness is on the plateaus)**	Generally rounded and sinuous; isolated plateaus of compressed, flattened grains and more loose, grainy low topography. Plateaus are smooth and irregular.	Flat; “double relief,” or surface flattening at one level, sharp edges, and interstices on a different level below. Plateaus are smooth and regular. Less amplitude (more regularization)	After 2 hours: flat and sinuous; broad, flat plateaus that round into the interstices; smooth and regular. After 4 hours: very smooth and grainy, flat, regular, loss of high/low topo. More translucent at 4 hours
Wear on grains	Compression and flattening on the plateaus, rounding at slopes and in interstices, some grain loss in interstices	Flattening and compressing/fusing on the plateaus, in the interstices there is some flaky buildup of compressed grains but it is looser, less fused.	After 2 hours: Rounding and smoothing, some compression/fusion on the plateaus. After 4 hours: rounding and shine, edge fusion but also grain loss which leads to increased graininess on the plateaus.
Linear traces	Small multi-directional striations, general irregular directionality Short, isolated	Directionality of abrasion evident, occasional rough striations, gouges	Very small striations, general directionality
Surface reflectivity	some isolated medium-highly reflective grains, discontinuous general low shine focused on the rounded plateaus	Generally matte, but discontinuous areas of discoloration (darkening) with higher reflectivity especially along the edges of plateaus and striations, some isolated highly reflective rounded grains	After 2 hours: high reflectivity across the tops of rounded grains and plateaus, medium reflectivity all over After 4 hours: general low reflectivity, some isolated medium-highly reflective spots on rounded grains.

(Dis)coloration	Some dull yellowing discoloration in a loosely reticulated pattern across the high plateaus	After about 5 hours, distinct pale yellow discoloration across some plateau surfaces, irregular distribution	The entire surface is saturated in a medium-dark yellowish coloration (from the oil); visible macroscopically as well.
High Magnification			
Micro-topography	More visible on areas with micropolish than on areas without	Same	
Large grain damage Note: in general, the grains were too soft to sustain much damage, flattening and fusing with neighboring grains before any discrete damage became visible. These descriptions refer to rare cases, therefore.	Compaction, occational crushing on a crystal, some grain loss in the interstices.	Crushing and compaction	Crushing and compaction (seen on micropolish), grain loss after 4 hours of use (as visible at low magnification)
Linear traces	Irregular multi-directional striations, across surface and also on compressed grains/micropolish.	Some superficial striations on compressed powder, some deeper striations, all irregular (not perfectly straight like stone/stone), but oriented along the axis of use.	micro-striations are much more evident after four hours at low magnification, but more evident after 2 hours on micropolish.
Micropolish? Note: All stones displayed a general overall glossiness that developed over the course of use; as this did not exist on unused surfaces, it is described as micropolish but seems to be related to the raw material and not as useful diagnostically as areas of higher development.	Y; described at two levels MP1: discontinuous transclucent shine throughout the high topography. MP2: highly developed polish on compressed grains/plateaus.	Y; Generally concentrated on the compressed grains along the tops of the edges of plateaus, as seen below.	Y; after two hours much more so than after four hours – after 2 hours, present in concentrated patches with evident directionality; after 4 hours only visible at higher magnifications in dispersed patches, very superficial. At 2 hours associated with plateaus, whereas at 4 hours with striations
Density Not useful/conflates with distribution	MP1: dense (across surface) MP2: isolated	Weakly developed across entire surface; patches of higher development are loosely concentrated	Same; very dispersed after 4 hours of use, however. At higher mag, areas with more or less polish visible
Boundaries	MP1: diffuse MP2: sharp	Diffuse	diffuse
Texture	MP1: superficial, rough MP2: smooth	smooth	Smooth/rough (2/4 hours)
Morphology	MP1: Sinuous MP2: flat-sinuous	As with barley	Flat after 2 hours, flat in isolated areas, also sinuous after 4

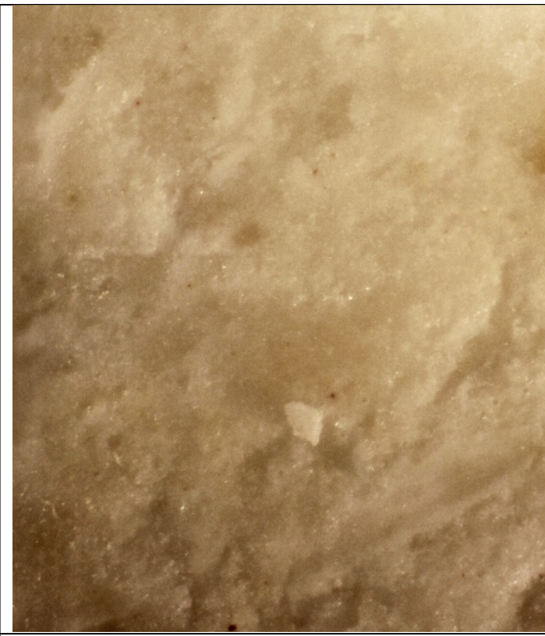
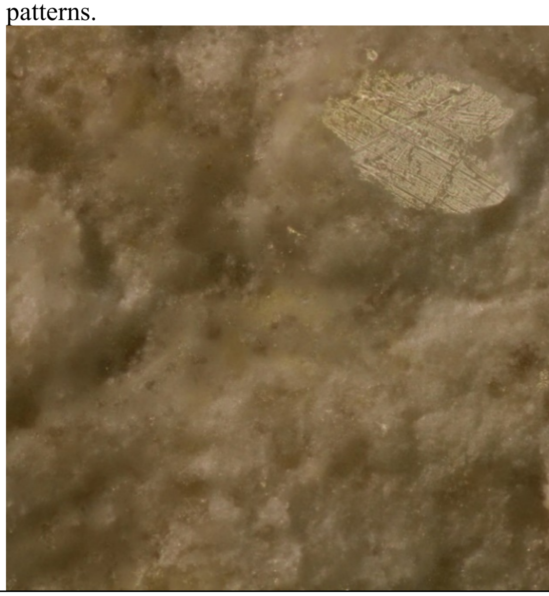
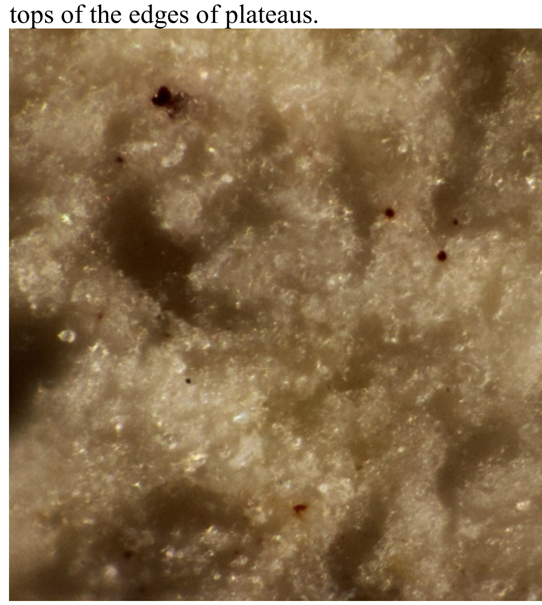
Orientation	MP1: none MP2: multi-directional	Along axis of use	Along axis of use (less so after 4 hours)
Distribution	MP1: Discontinuous, reticulated MP2: Isolated	Discontinuous	At lower magnification, polish vs no polish - Associated with plateaus, or striations at 4 hours – loose pattern and not well connected at 2 hours, slightly better connected at 4 hours along striations
Opacity	Translucent	translucent	translucent
Reflectivity	MP1: Low MP2: Medium-high	Low-medium	low

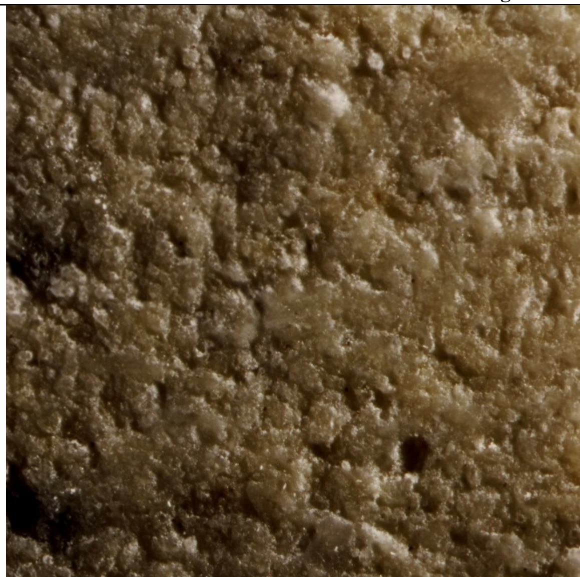
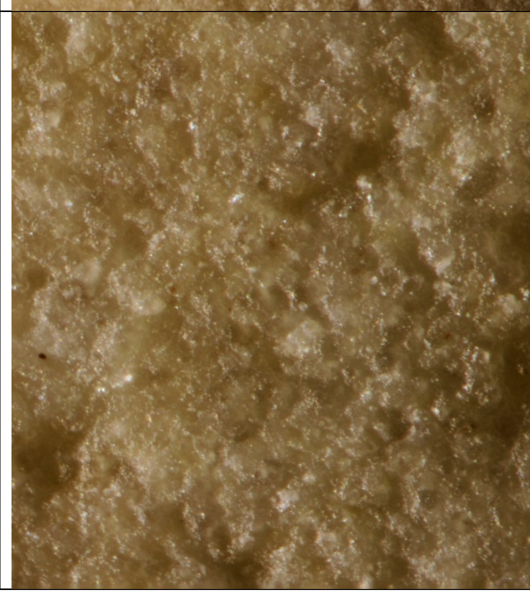
BARLEY		SALT
Low Magnification		
Topo, roughness	Generally rounded or sinuous; isolated plateaus of compressed, flattened grains and more loose, grainy interstices. Irregular roughness, moderate continuity between plateaus and interstices. Top is at x20, bottom at x80  	Flat, fused, flaky texture across the surface – “double relief,” or surface flattening at one level, abrupt edges, and interstices on a different level below. Irregular smoothness, low continuity between plateaus and interstices. Top at x20, bottom at x80.  

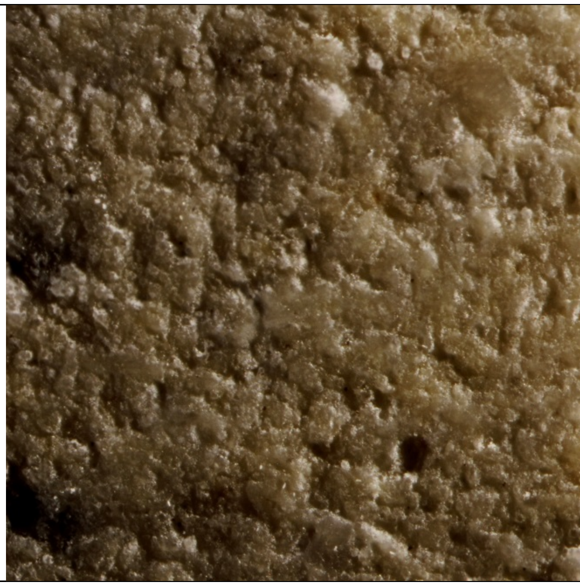
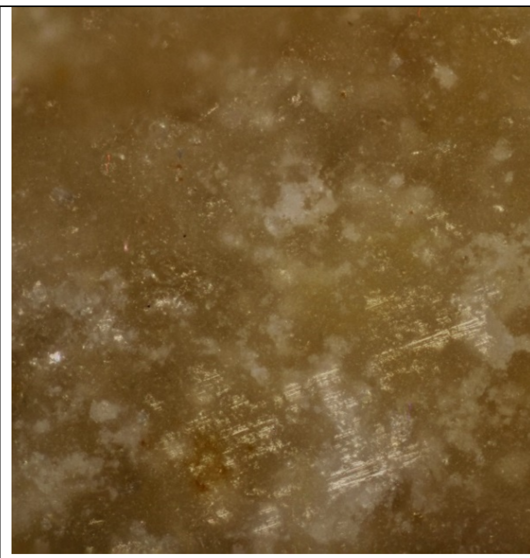
Wear on grains	Compression and flattening on the plateaus, rounding at slopes and in interstices, some grain loss in interstices 	Flattening and compressing/fusing on the plateaus, in which there is some flaky buildup of compressed grains but it is looser, less fused. 
Linear traces	Small multi-directional striations, general irregular directionality 	Directionality of abrasion evident, occasional rough striations, gouges 
Surface reflectivity	some isolated highly reflective grains, discontinuous general shine focused on the rounded plateaus	Generally matte, but discontinuous areas of discoloration (darkening) with higher reflectivity especially along the edges of plateaus, some isolated highly reflective rounded grains

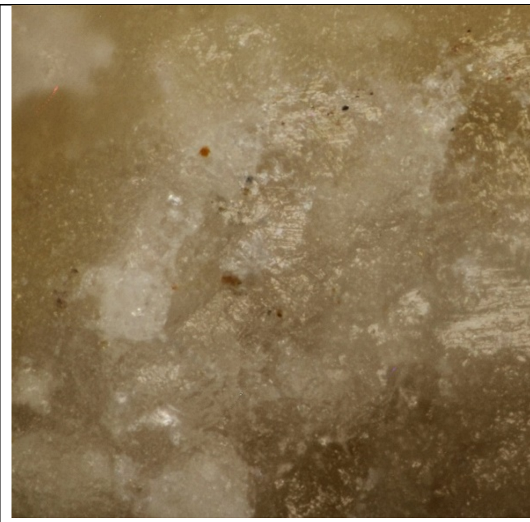
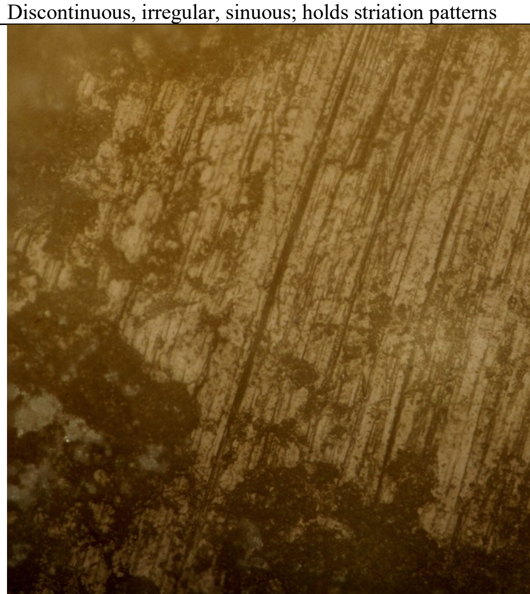
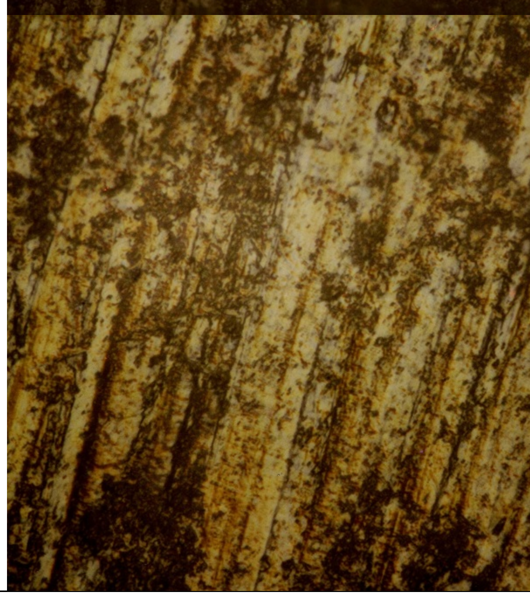
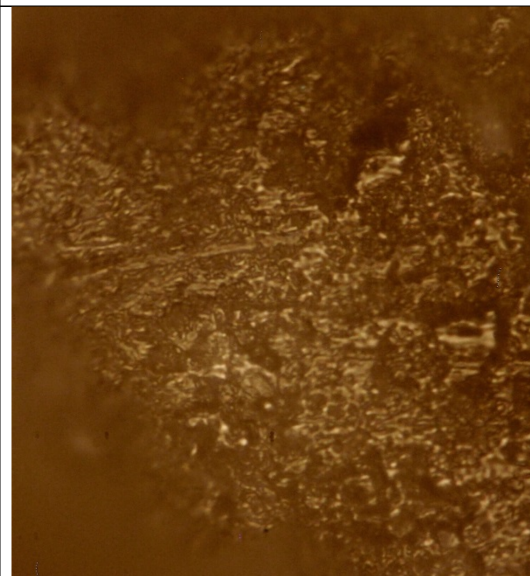
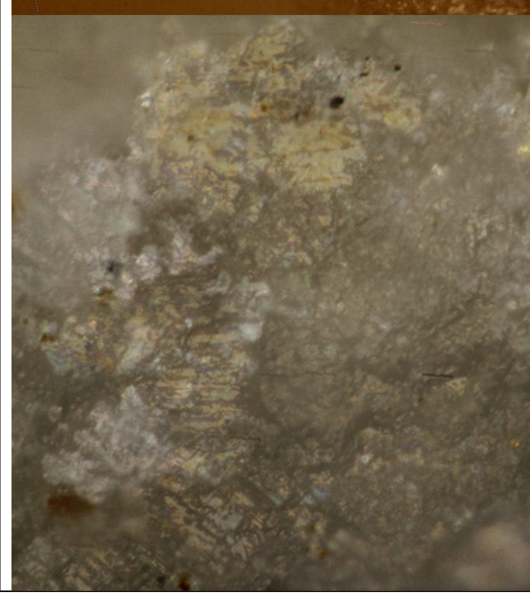
		
High Magnification		
Micro-topography	Sinuous (Dubreuil et al 2016’s « fluid ») general topography, compression wear is most highly developed on grain and plateau surfaces but extends over the edges of plateaus and is weakly developed throughought interstices with some grain loss/irregular roughness. A generalized multi-layered appearance is due to the development of soft powder surface shine overlaying the lower topography (but this would likely not remain archaeologically). 	Flat and smooth; some irregular plateaus remain where harder quartzite crystals are present, disrupting overall smoothness; soft grains are crushed and flattened, powder gathers around irregular grains and plateaus, abrupt/ rough boundaries 
Large grain damage	Not really present; large grains are crushed and then fuse into compressed plateaus, as below, or fall out – grains appear to generally be too soft to sustain major damage and remain on the surface.	Grains tend to crush and the powder fuses and is distributed and flattened across the rest of the use surface before they display granular damage. Grain loss in interstices. Abrupt transitions

		between plateau and interstice. 
Surface Reflectivity	Low-level shine across the entire surface, high reflectivity on quartzite inclusions and some higher reflectivity along edges of crushed plateau surfaces. 	See image above: generally matte, low reflectivity. Discoloration seen at macro level is isolated to tops of plateau surfaces and likely corresponds to underlying minerology, exposed via the removal of surface grains and powder.
Linear traces	Irregular multi-directional striations, across surfaces of compressed grains/micropolish (see image below). None visible in general surface matrix.	Some superficial striations on compressed powder, some deeper striations, all irregular (not perfectly straight like stone/stone), but oriented along the axis of use.

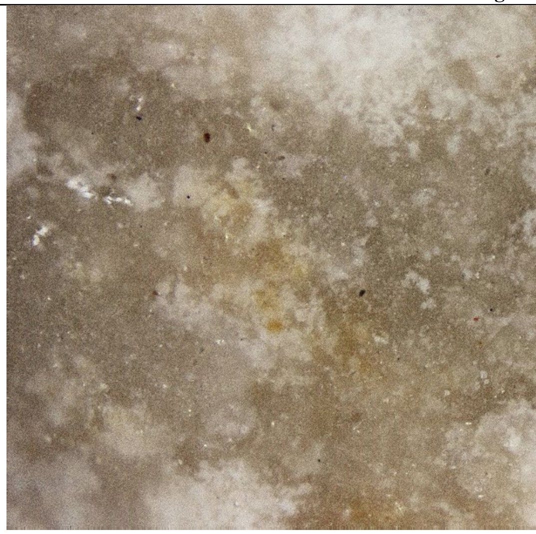
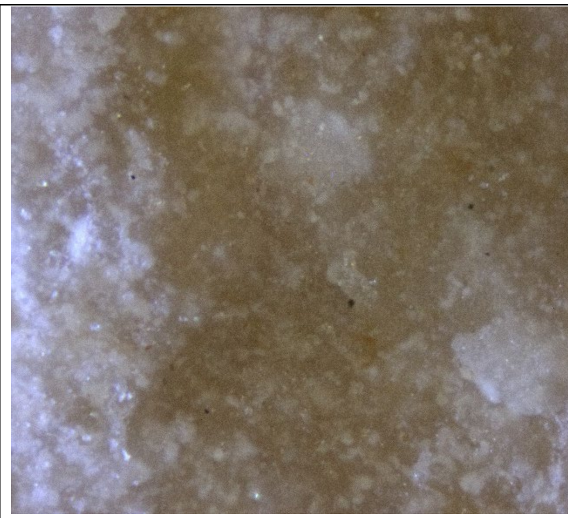
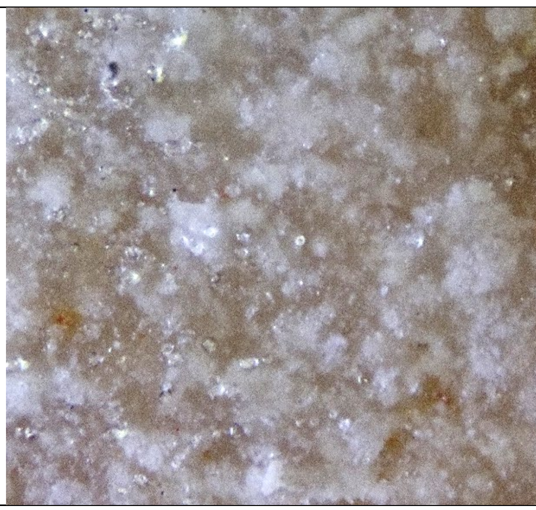
		
Micro-polish?	Yes; discontinuous transclucent shine over the plateaus, small isolated areas of high polish on compressed grains with clear directional striation patterns. 	Yes, but weakly developed. Generally concentrated on the compressed grains along the tops of the edges of plateaus. 

Flax (oily)		
	2 hours	**10 hours**
	Low Magnification	
Topo, roughness		
Wear on grains		

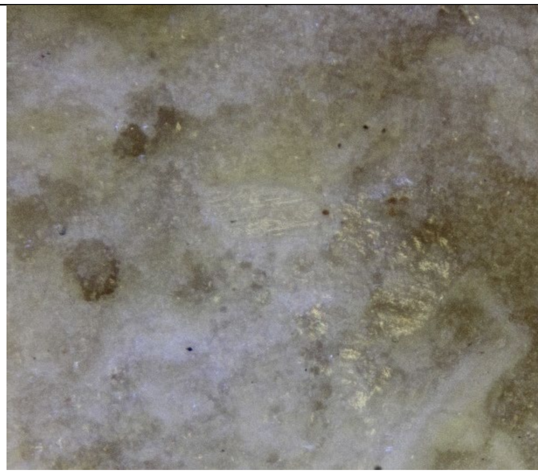
Linear traces		
reflectivity	See above	See above
	High Magnification	
Micro-topography; Large grain damage; Linear traces Note: this shows that these are more visible in areas with micropolish than without; see images below, as well	 Weak striations, seen to continue through micropolish, flattening and compression of grains, smooth/oily surface texture.	

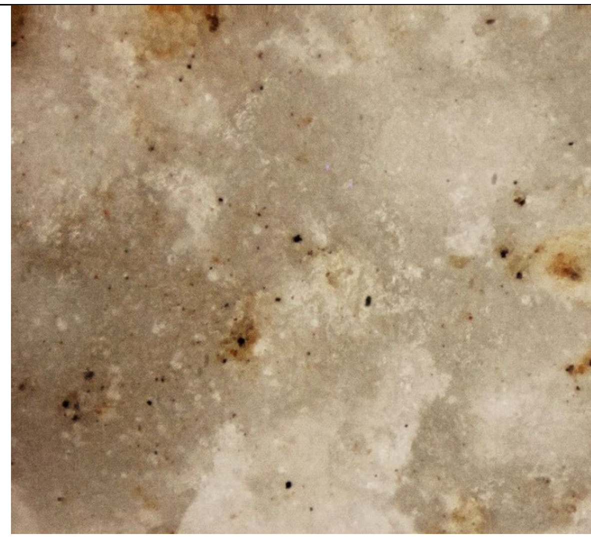
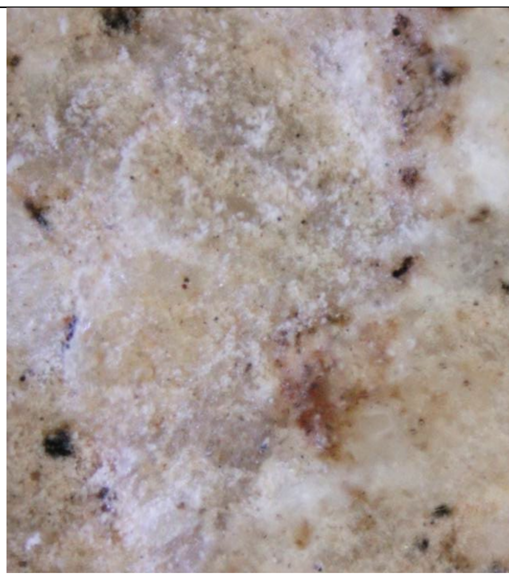
Micropolish	 Discontinuous, irregular, sinuous; holds striation patterns	
Texture, morphology, orientation, opacity, reflectivity L= x200, x500 R=x500, x500	 	 

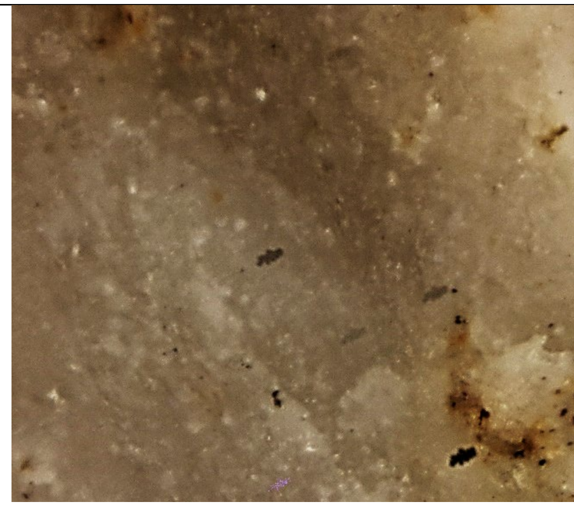
Experiments on Limestone – 2016 – AUB – Toasted Chickpea Images

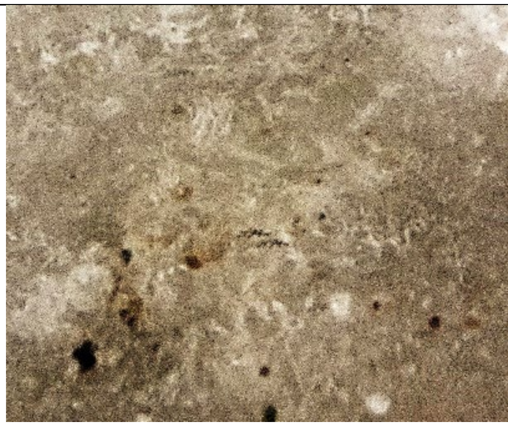
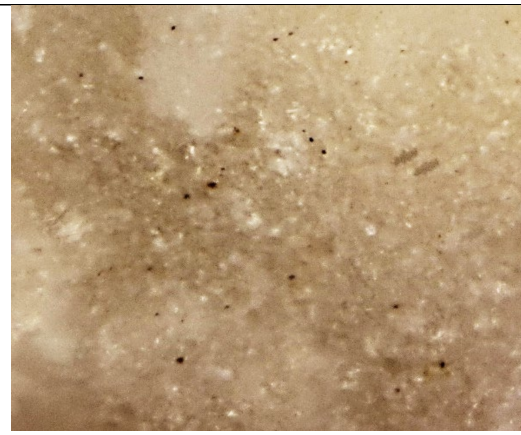
Toasted Chickpea (Dry Grainy/Abrasive)		
2 hours		10 hours
	Low Magnification	
Topo, roughne ss		
Wear on grains		

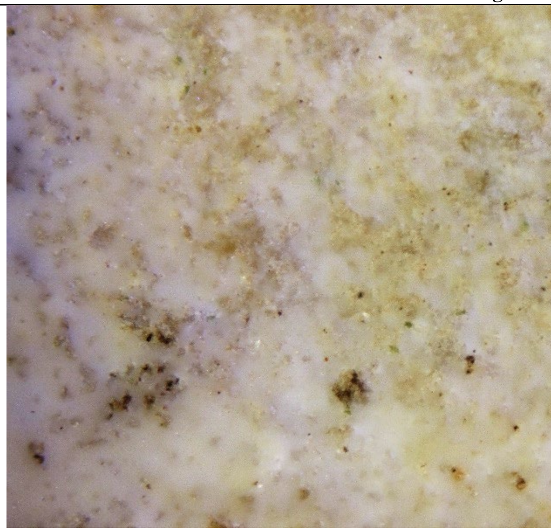
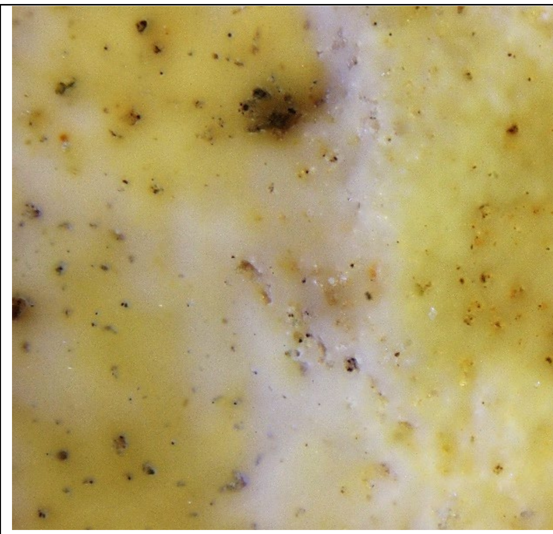
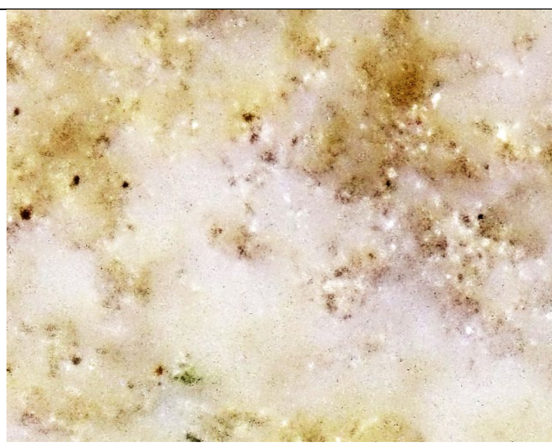
Linear traces, discoloration and reflectivity		
	High Magnification	
Micro-topography; Large grain damage; Linear traces Note: this shows that these are more visible in areas with micropolish than without; see images below, as well		

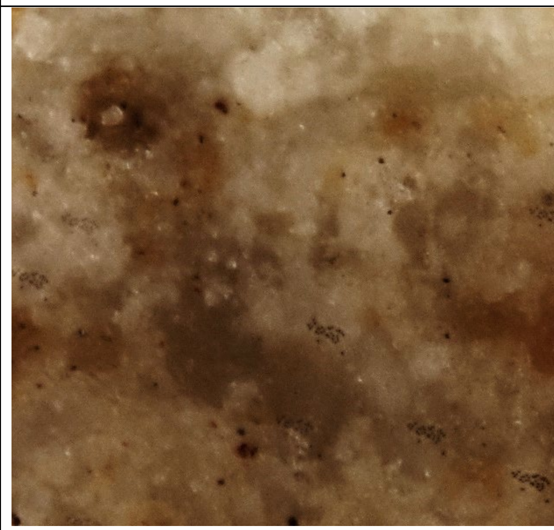
Micropo lish		

Goat bone (splintery/oily)		
	2 hours	**10 hours**
	Low Magnification	
Topo, roughness	 Medium roughness, sinuous and "flaky"; tops of plateaus are smoothed but some flakiness in overall aspect.	 "Flakiness" typical of bone working starts to develop, as powder accumulates in discontinuous, uneven patches like flakes on the topography.
Wear on grains	 Compression rather than crushing, grain loss in interstices and powder accumulating around crystal inclusions.	 Powder accumulation largely settled into "flaky" plateaus (left of image) and not clustered around crystal inclusions (right). Smoothing of grains withi minimal grain loss.

<table>
<tr><td>Linear traces</td><td>
Striations lightly developed, clustered, multi-directional, but significant grain loss and gradual powder accumulation obscures the patterning and depth.</td><td>
Clusters of small “splintery” micro-striations in multi-directional, isolated groups across the surface, as most grain loss has been removed by this point, traces are more visible as part of the stone matrix rather than on top of accumulated powder (which is becoming distinct flakes).</td></tr>
<tr><td colspan="3">High Magnification</td></tr>
<tr><td>Micro-topography; Large grain damage; reflectivity; discoloration</td><td>
Adams’ (2014) “levelling off” of plateaus, sinuous and smooth with some grain loss producing roughness along interstices, crushing on the larger grains and plateaus forming around the compressed powder from crushed grains. Generalized “double relief” reflective shine. Brown spots are irregular inclusions, not discoloration from wear.</td><td>
Original granular plateaus largely leveled off, but compressed powder plateaus remain. Irregular discoloration (yellowish); reflectivity is generalized across the surface but lower than intensity than at earlier stages. Crushed grains have largely fallen out but irregular powder accumulations remain, leaving a smooth but flaky topography.</td></tr>
</table>

Micropo lish	 Discontinuous over the top and sides of low plateaus; irregular boundary, sinuous texture	 Difficult to detect at this magnification without DIC, but appears to be degraded but still present in discontinuous patches across the upper relief of the micro-topography. Not isolated to any particular surface area, as plateau-interstice boundaries are smoother and more continuous.

Goat Hide (Oily/Soft)		
	2 hours	**10 hours**
	Low Magnification	
Topo, roughness	 Very smooth and sinuous, some grain loss in interstices as the boundaries begin to be smoothed but it has not yet reached the bases.	
Wear on grains	See above; grain loss, overall smoothing compresses grain surfaces without crushing or impact fracturing. Low powder accumulation.	See above; no crushing or fractures, but overall compression and smoothing – individual grains no longer visible. No powder accumulation.
Linear traces, discoloration and reflectivity	 Discontinuous yellowing of surface areas, both plateaus and interstices. No linear traces. Generalized overall low reflectivity.	As with fewer wear hours, reflectivity highlighted along edges of plateaus, but plateaus themselves have fairly low-level reflectivity.
	High Magnification	

Micro-topography; Large grain damage; Linear traces Note: this shows that these are more visible in areas with micropolish than without; see images below, as well	 Plateau (left) and interstice (right): Boundary is completely smoothed, traces of minimal grain loss in interstice but no roughness (grain cavities also smoothed). Patchy black discoloration due to camera error, not stone.	 Smooth and sinuous, not flattened – all boundaries are smoothed but not reduced, overall low sheen/reflectivity with possible light polish development in isolated patches (right/upper right side).
Micropolish	Not well developed; more general high reflectivity than micropolish, although DIC would help distinguish the two.	 Very light possible polish across plateau surfaces on the edge of a smoothed interstice; difficult to show in a picture without high/low focus to see the double relief effect, but in any case weakly developed, discontinuous, sinuous texture that follows the microtopography.